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The influence of enclosure design on diurnal activity and stereotypic behaviour in captive Malayan Sun bears (*Helarctos malayanus*)

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ABSTRACT

The effect of enclosure design on diurnal activity and stereotypic behaviour was assessed in 17 adult Malayan Sun bears (*Helarctos malayanus*), kept either in barren indoor enclosures or relatively enriched outdoor enclosures. Locomotion was the most frequent activity observed in the indoor bears, followed by resting. In contrast, conspecifics housed outdoors spent most of the time resting. Eleven forms of stereotypic behaviours were recorded in the bears, with pacing being the most common. The frequency and repertoire of stereotypies were significantly higher in the indoor bears irrespective of enclosure size. Novel forms of locomotor (forward-reverse pacing) and oral (allo-sucking) stereotypies were recorded. Oral stereotypies were predominant in the bears housed indoors, while patrolling was confined to the outdoor bears. Enclosure complexity significantly influences activity budget and occurrence of stereotypic behaviours, highlighting the importance of appropriate enclosure design and enrichment for the welfare of captive bears.

1. Introduction

Captive animals are subjected to an environment that differs greatly from their natural habitat, often restricting them from performing natural behaviours. Conditions of the captive environment have been shown to limit the repertoire and also the amount of time spent engaging in innate activities (Stolba et al., 1983; Shepherdson et al., 1993; Veasey et al., 1996; Swaisgood et al., 2001; Young, 2003; van Tuly, 2008). In addition, these artificial environments often do not promote interaction with the surroundings, which is important for the development of sensory and cognitive abilities, and the expression of species-specific behaviours (Morgan and Tromborg, 2007). The restrictions in the expression of normal behaviour in captive animals often lead to stress and frustration, which are detrimental to their welfare (Friend, 1989). Chronic stress invariably leads to the development of abnormal behaviours (Schouten and Wiegant, 1997; Carlstead and Brown, 2005), which are of concern to zoo managers because of their association with sub-optimal captive conditions and poor animal welfare (Mason, 1991a). In addition, chronic stress due to unsuitable captive environments increases activities such as behavioural inhibition (Carlstead et al., 1993a; Vyas and Chattaji, 2004; Carlstead and Brown, 2005), vigilant behaviour (Carlstead et al., 1993a), and compromises the reproductive potential (Shepherdson, 1994; Chrousos, 1997), immune response (Barnett et al., 1992; Ferrante et al., 1998) and overall health (Broom and Johnson, 1993; Sapolsky, 1996) of captive animals. It is well established that while certain zoological species thrive in captivity, others are often difficult to maintain without behavioural problems and breeding difficulties (Clubb and Mason, 2003).

Cage stereotypies, defined as behavioural patterns that are repetitive, invariant and apparently functionless (Odberg, 1978; Mason, 1991b) are a commonplace in captive zoo animals, and are of growing concern due to their negative implications. While the exact underlying mechanism is yet to be elucidated, this anomaly has been associated with perseveration, as the captive environment is hypothesised to alter behavioural organization by affecting the functionality of the striatum that is involved in the selection and ordering of behavioural patterns (Garner, 1999; Garner and Mason, 2002). In order to reduce the occurrence of stereotypic behaviour and improve the welfare of captive zoological animals, zoo communities have initiated enrichment strategies to enhance captive environment (Young, 2003; Swaisgood and Shepherdson, 2005). Experimental enrichment programs often involve the improvement of the physical characteristics of enclosures, incorporating structural changes to increase the complexity of the environment and to promote interactive and exploratory behaviour (Mason et al., 2007). It has been shown that improving the captive environment alleviates the occurrence and frequency of behavioural anomalies and stereotypies (Carlstead et al., 1991; Grindrod

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and Cleaver, 2001; Swaisgood and Shepherdson, 2005), reduces fearfulness (Reed et al., 1993) and also allows the animal to better manage confinement-related stress (Carlstead et al., 1993b).

Throughout the world, bears are commonly housed in zoological parks for public viewing, captive breeding, conservation and education purposes. In contrast to their natural habitat, captive bears are generally confined in small and barren enclosures with a fixed routine. In such monotonous and non-stimulating environments, bears tend to perform stereotypies (Carlstead et al., 1991; Wechsler, 1991; Forthman and Bakeman, 1992). Since the first report of an unusual behaviour of hind-foot sucking in captive Malayan Sun bears (*Helarctos malayanus*) by Dathe (1975), a wide repertoire of stereotypic behaviours has been documented in captive ursids including locomotor, deprivative, and oral repetitive behaviours (Vickery and Mason, 2004).

The Malayan Sun bear (*H. malayanus*) is the smallest of the extant bear species and inhabits the equatorial lowland rainforest of parts of mainland Asia and its adjacent islands (Servheen, 1999). Its natural habitat is predominantly the dense lowland dipterocarp forests, but they may also be found in lower montane, swamps, mixed secondary forests and plantations (Lekagul and McNeely, 1977; Medway, 1983; Francis, 2008). Currently listed as "Vulnerable" in the IUCN Red List of Threatened Species 2011 (Fredriksson et al., 2008), this bear species remains the least researched member of the Ursid family (Pereira et al., 2002; Servheen, 1999). The lack of biological information on *H. malayanus* has been recognized as a serious limitation to conservation efforts, and it has been advocated that research on this species should be of the highest priority for any bear species worldwide (Servheen, 1999). A number of studies have documented the captive behaviour of *H. malayanus* (Hewish and Zainal-Zahari, 1995; Vickery and Mason, 2004, 2005), however, there remains a paucity of published information on the effect of enclosure design on the behaviour patterns and manifestation of stereotypies in this species. In this paper, we present comparative data on the diurnal activity budget and stereotypic behaviour of captive *H. malayanus* housed in barren indoor and enriched outdoor enclosures, in order to elucidate the effect of enclosure design on the behaviour of these bears in captivity. We also constructed an ethogram of normal and stereotypic behaviour of *H. malayanus* in captivity.

2. Materials and methods

2.1. Animals and housing

Seventeen adult *H. malayanus* (5 males and 12 females) housed in two separate zoos (Zoo-A and Zoo-B) were observed in this study. Based on the zoo records, the age of the bears ranged from 3 to 23 years at the beginning of the observation. All the bears were acquired from the wild and donated to the zoos, except for a female that was born at Zoo-A in 1998. All bears were reared in captivity for a minimum period of one year prior to the commencement of the study.

In Zoo-A, four bears were released into an outdoor enclosure (109.3 m^2) between 0930 and 1630 h for public viewing and were coaxed back to the night stalls with food in the evening. The enclosure was enriched with a pond (8.1 m^2) and an artificial tree (2.5 m diameter × 5 m height), which allowed the bears to climb and rest (Fig. 1a). Another four bears were kept as pairs in two separate indoor enclosures (9.6 m^2) with a concrete floor and walls made of metal bars and concrete throughout the observation period. Apart from a sleeping platform erected approximately 1 m above the floor and a water trough, the indoor enclosures were barren. These indoor enclosures were not open for public viewing. Five bears in Zoo-B were released into an outdoor enclosure (380 m^2) between 0930 and 1730 h for public viewing. The enclosure included a perimeter dry moat, enabling the bears to climb down and move freely within it, an L-shaped pond (37.5 m^2), and several vertically and horizontally placed tree logs (Fig. 1b). Four other bears were kept as pairs in two separate concrete floor indoor enclosures (3.75 m^2) with walls made of concrete and metal bars. There was no furniture in the indoor enclosures except for a cement water trough on the floor. Detailed description of the enclosures and animals are presented in Table 1. Bears in both zoos were fed once daily with bread, milk and assorted tropical fruits. All animals were fed after the observation ended in the evening.

2.2. Data collection

Three to four weeks prior to the start of the experiment, all the bears were sedated with Tilatemin/Zolazepam (Zoletil 100, Virbac, 5 mg/kg), in order to conduct a health screen, which involved a general physical examination, a visual screen for ectoparasites, coprological evaluation for endoparasites, and haematologic and serum biochemical analyses. Blood was drawn from the medial saphenous vein of the anaesthetized animals using 18 gauge needles and placed into ethylenediaminetetraacetic acid (EDTA) coated blood collection tubes (BD Vacutainer®). Blood samples were transported on ice to the laboratory for further processing. Serum biochemistry values were determined using an automated biochemistry analyser (Roche Hitachi 902, Roche Diagnostics, Germany) with standard commercial kits (Roche Diagnostics, Germany). Total cell counts were done using an automated haematology counter (ABC Vet, Horibar-ABX, France). Differential white blood cell counts were determined by microscopy examination of blood smears stained with Wright Stain. Packed cell volume was obtained by the micro-haematocrit technique using a micro-haematocrit reader (Hawsley Micro-Haematocrit Reader, England). Plasma protein concentration was measured with a refractometer (Atago T2-NE, Atago Co. Ltd., Japan).

Behavioural observations were done using a scan sampling method for 14 consecutive days in each zoo. The animals and observers were conditioned to the behavioural observation protocol for seven days prior to actual data collection. Data were recorded by instantaneous sampling at 10 min intervals (Martin and Bateson, 2007). Daily observations started between 0910 and 0950 h after the bears were released into their enclosures and ended approximately 30 min before the bears returned into their night stalls (1520 h in Zoo-A and 1630 h in Zoo-B). A minimum of 35 scans was done each day for each individual. The ethogram and parameters recorded during the observation (Table 2) include original descriptions from observations in this study and adaptations from other sources (Hewish and Zainal-Zahari, 1995; Liu et al., 2003; Montaudouin and Le Pape, 2004; Vickery and Mason, 2004).

2.3. Data analysis

All data were analysed using IBM SPSS Statistics 20 for Windows. The frequency of each activity was the relative percentage score of the total amount of activities. Data from animals kept under similar conditions (indoor or outdoor) in the same zoo were pooled. When computing activity budgets, locomotory stereotypy was grouped under "Locomotion" while other forms of stereotypic behaviours were classified as "Other stereotypies". Non-parametric Mann–Whitney U-test was performed to detect differences in activity budget and stereotypic behaviour between

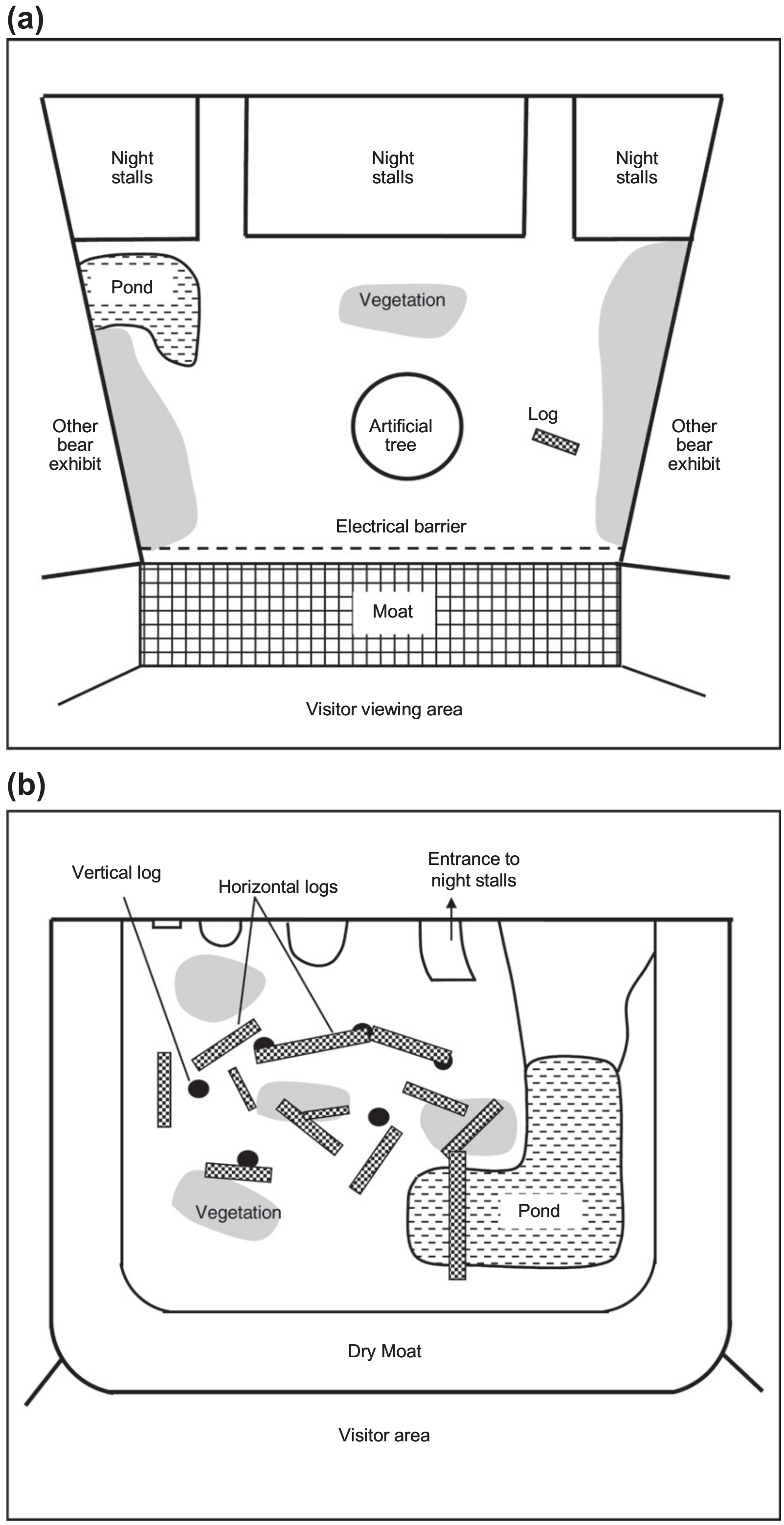

Fig. 1. Layout of the outdoor enclosure of *Helarctos malayanus* at (a) Zoo-A ($N = 4$) and (b) Zoo-B ($N = 5$).

indoor and outdoor bears. Statistical significance ($P < 0.05$) of the haematological and serum biochemical values between the individuals performing coprophagia and those not engaged in coprophagia was explored using a one way analysis of variance (ANOVA). Values reported represent the mean and standard deviation (SD).

3. Results

3.1. Health screen

All the bears were healthy upon physical examination and were free of ecto- and endoparasites. The haematologic and serum

Table 1
Description of the enclosures and signalment of captive *Helarctos malayanus* subjected to behavioural observations in Zoo-A and Zoo-B.

Zoo ID	Description of enclosure	Animals	
		Sex	Age (years)
Zoo-A	Outdoor, 109.3 m^2	Female	23
	Substrate – grass and earth	Female	9
	Pond (8.1 m^2)	Female	19
	Artificial tree (2.5 × 5 m Height)	Male	20
	Log on ground		
	Tree shade available		
	Indoor, 9.6 m^2	Female	19
	Substrate – concrete floor	Female	12
	Raised platform (1.2 × 0.8 m)		
	Indoor, 9.6 m^2	Female	4
	Substrate – concrete floor	Male	3
	Raised platform (1.3 × 1.5 m)		
Zoo-B	Outdoor, 380 m^2	Female	17
	Substrate – grass and earth	Female	16
	Pond (37.5 m^2)	Female	12
	Vertical and horizontal logs	Female	10
	Platforms	Male	16
	Dry moat		
	Indoor, 3.75 m^2	Male	6
	Substrate – concrete floor	Female	7
	Steel bars and plates		
	Indoor, 3.75 m^2	Male	7
	Substrate – concrete floor	Female	3
	Steel bars and plates		

biochemistry values for the bears were within the normal range reported for the species, except for six bears that had slight decrease in sodium and three with slight elevations in cholesterol. The bears performing coprophagia showed significantly lower ($P < 0.05$) values for two parameters, namely, band neutrophils and glucose, compared with conspecifics that did not engage in this activity. Mean haematologic and serum biochemical values for both these groups are presented in Table 3.

3.2. Diurnal activity budget

The bears maintained in similar enclosures at both zoos had similar diurnal activity profiles (Fig. 2). Locomotion was the most frequent activity observed in the indoor bears (Zoo-A: 44.0 ± 18.7%; Zoo-B: 36.2 ± 12.3%), followed by resting (Zoo-A: 22.8 ± 14.8%; Zoo-B: 25.7 ± 11.0%). In contrast, resting was the most common activity in the bears housed outdoors (Zoo-A: 58.3 ± 15.6%; Zoo-B: 52.0 ± 20.1%), followed by locomotion (Zoo-A: 28.4 ± 14.2%; Zoo-B: 23.1 ± 13.5%). Reproductive behaviour was not observed in both zoos throughout the observation period. When comparisons were made between indoor and outdoor bears in Zoo-A, the frequency of resting was significantly higher in the outdoor bears (Mann–Whitney U test: $U = 168$, $N_1 = N_2 = 4$, $P < 0.05$) while the frequencies of locomotion ($U = 829$, $N_1 = N_2 = 4$, $P < 0.05$), investigation ($U = 860$, $N_1 = N_2 = 4$, $P < 0.05$), conspecific interaction ($U = 268$, $N_1 = N_2 = 4$, $P < 0.05$), interact with humans ($U = 1024$, $N_1 = N_2 = 4$, $P < 0.05$) and other stereotypies ($U = 902$, $N_1 = N_2 = 4$, $P < 0.05$) were significantly higher in the indoor bears. In Zoo-B, the outdoor bears spent significantly more time resting ($U = 556$, $N_1 = 5$, $N_2 = 4$, $P < 0.05$) and interacting with humans ($U = 813$, $N_1 = 5$, $N_2 = 4$, $P < 0.05$) than the indoor bears. On the other hand, maintenance ($U = 607$, $N_1 = 5$, $N_2 = 4$, $P < 0.05$), locomotion ($U = 860$, $N_1 = 5$, $N_2 = 4$, $P < 0.05$), conspecific interaction ($U = 1560$, $N_1 = 5$, $N_2 = 4$, $P < 0.05$) and solitary play ($U = 1628$, $N_1 = 5$, $N_2 = 4$, $P < 0.05$) were more frequently observed in the indoor bears compared with their conspecifics housed outdoors.

3.3. Stereotypic behaviour

Stereotypic behaviour was highly prevalent in this study, where all the bears were observed to perform at least one form of stereotypy. In both zoos, indoor bears showed a significant higher frequency of total stereotypy (Fig. 3; Zoo-A: $U = 801$, $N_1 = N_2 = 4$, $P < 0.05$; Zoo-B: $U = 134$, $N_1 = 5$, $N_2 = 4$, $P < 0.05$). Locomotory stereotypy, especially pacing, was the predominant type of stereotypy observed in all four groups of bears. No deprivative stereotypy was seen in the outdoor bears in both zoos. A total of 11 forms of stereotypic behaviours were recorded in both zoos (Fig. 4a and b). Eight forms of stereotypic behaviours were observed in the bears in Zoo-A (Fig. 4a). Pacing was the most apparent form of stereotypy in both the indoor and outdoor bears (indoor: 30.4 ± 17.3%; outdoor: 13.7 ± 11.8%). However, the frequency of pacing was significantly higher ($U = 688$, $N_1 = N_2 = 4$, $P < 0.05$) in the animals housed indoors. Patrolling was only observed in two individuals of the outdoor group, while other locomotory stereotypy, self-sucking, bar-licking, bar-biting and coprophagia were only observed in the indoor bears. Seven forms of stereotypic behaviours were observed in the bears kept in Zoo-B (Fig. 4b). As observed in Zoo-A, pacing was the most common form stereotypic behaviour observed in both the indoor and outdoor groups. The frequency of pacing in the indoor bears (26.7 ± 11.9%) was approximately five-times greater than of the outdoor bears (5.0 ± 8.3%; $U = 210$, $N_1 = N_2 = 4$, $P < 0.05$). In both institutions, more forms of stereotypic behaviour were observed in the indoor groups. The percentage of bears performing the various stereotypic behaviours in both zoos and housing conditions is presented in Fig. 5. Self-licking, regurgitating, and coprophagia were only observed in the bears housed indoors, while tongue-flicking was only seen in the ones housed outdoors. Oral stereotypy was more frequently observed and more diverse in forms in indoor than outdoor bears regardless of the feeding time. Self-sucking was observed in 10 out of 17 bears studied, and was seen to be performed by all the indoor bears. The common anatomical sites that they sucked were the carpal joints and toes. This group also commonly (63%) performed self-licking.

4. Discussion and conclusions

The enclosure environment had a significant effect on behavioural budgeting and also the repertoire of stereotypic behaviours exhibited by the bears in both institutions. The most frequent behaviour shown by the outdoor bears was resting, while their indoor conspecifics spent a considerable amount of time engaging in stereotypic locomotory activities. The dominant resting behaviour in *H. malayanus* housed outdoors is in agreement with a previous report (Hewish and Zainal-Zahari, 1995) and may be largely attributed to the provision of suitable furniture like artificial trees, hides or raised platforms that served as comfortable resting sites. On the contrary, the small enclosure size and lack of essential stimuli for guiding natural behaviours in the indoor captive environment may be among the reasons for the high incidence of locomotor stereotypies in the bears housed indoors. Interestingly, indoor bears that were kept in pairs spent more time interacting with their cage mate than did outdoor bears that were kept in groups of four or five. A previous study on brown bears (*Ursus arctos*) concurred with these findings; more playful interactions were observed when the bears were paired rather than placed in groups (Montaudouin and Le Pape, 2005). However, in this study, it is important to point out that the indoor enclosures were barren, small, and poorly furnished while the outdoor enclosures were relatively large and enriched. Thus, the stimuli available for indoor bears were possibly very limited to their cage mate. In addition, the indoor bears were

Table 2
Ethogram of normal and stereotypic behaviours of *Helarctos malayanus* observed during this study, with adaptations from other studies as indicated.

Behavioural Group	Behavioural Subgroup	Definition
Normal behaviours		
Maintenance	Ingestion	
	Feed	Voluntary ingestion of edible material [a]
	Drink	Voluntary ingestion of liquids
	Elimination	
	Urinate	Elimination of urine from body
	Defaecate	Elimination of faeces from body
	Auto-grooming	
	Lick	Repeated movement of the tongue over the surface of the body.
	Scratch	Repeated rubbing action of a section of the body's surface using its claws
	Rub	Friction between part of the body against either a blunt object, or another portion of the body
	Shake	Voluntary rapid movement of the head or part of the body back and forth
	Swat insects	Striking insects on its body or other limbs with its front paws
	Comfort seeking	
	Rest in water	Sitting, standing or lying in the water
Resting	Alert	Attentive and highly responsive to stimuli [b]
	Asleep	Sitting or lying with body motionless and eyes closed; does not appear alert [a]
Locomotion	Stand	To maintain an upright position on extended legs, with equal distribution of weight bipedally or quadrupedally
	Walk	Propulsive force derived from either bipedal or quadrupedal movement which results in low speed of locomotion
	Run	Propulsive force derived from quadrupedal movement which results in high speed of locomotion
	Climb	Ascending or descending movement on vertically or placed structures
	Stretch	Brief extension of limbs or body
Investigation	Sniff	Brief inhalation of object, ground or air during olfactory investigation for a period of more than 5 s [b]
	Dig	Breaking up soil or creating a hole in the ground with its paws
Behavioural group	Behavioural subgroup	Definition
	Scratch	Scraping the surface of an object or structure with its claws
Conspecific interaction	Contact	
	Sniff	Olfactory investigation of parts of the body of a conspecific when in close proximity
	Lean	Partial support of head or body on conspecific
	Nuzzle	Performing rubbing or stroking movements with face or muzzle towards a conspecific
	Allo-grooming	Grooming a conspecific
	Social play	
	Play fight	Energetic, non-aggressive pursuit and wrestling with a conspecific
	Chase	Energetic, non-aggressive pursuit of a conspecific
Aggression	Displace	Forceful removal a conspecific from its original position, physically and/or by vocalisation
	Threaten	Snout wrinkled upwards with mouth open, showing canines, and often vocalising loudly [c]
	Attack	Violent attempt to injure another individual, by swiping its paws and trying to bite [c]
Solitary play	Object play	Hold, pull and/or stretch an object, or putting the object into its mouth
	Non-object play	Roll, turn or manipulate own body parts in a relax manner
Interaction with human	Attentive to human	Move towards and/or maintaining eye contact the attended person(s)
	Interact with human	Stand on hind limb while facing the attended person(s), often with eye contact
Stereotypic behaviours		
Locomotor stereotypy	Pace	
	Standard pace	Continuous walk back and forth in a repetitive way for at least three times [d]
	Forward-reverse pace	Continuous walk between two points, by stepping forwards and then backwards without turning the body
	Weave	Locomotion (to left and right alternately) with body perpendicular to cage bars or wall; fore feet occupy two or more positions; hind feet may be lifted and repositioned or only shuffled [a]
	Patrol	Locomotion tracing a certain path (a circular, elliptical or irregular route) [a]
	Sway	Rocking of the head from side to side continuously when standing in front of the cage door or of the fence [e]
	Head throw	Throwing head back and over shoulder during locomotion[a]
	Others	Other locomotory stereotypies that are not categorized above
Oral stereotypy	Self-lick	Repetitive licking of a body area with constant movements [a]
	Self-suck	Repetitive sucking of part of own body that is often accompanied by a distinct 'humming' vocalisation [a]
	Allo-suck	Repetitive sucking of a part of conspecific's body area
	Bar lick	Tongue is held against cage bars for more than 30 s, and may be curled around or pressed up against bars [a]
	Bar bite	Repetitive biting of cage bars or other metal structures
	Sham chew	Jaws are moved as though food is being chewed, but the mouth is empty [a]
	Jaw clamp	Teeth are clamped together repetitively [a]
	Regurgitating	Food taken into the mouth, chewed, and retched onto paw or any other surface repeatedly
	Tongue flick	Tongue is flicked in and out of mouth [a]
	Tongue curl	Tongue is extended and curled up and around muzzle [a]
	Foaming	Large amounts of white foamy saliva are produced and held in the mouth, allowed to drip down over the jaw and/or hurled from the mouth by rapid back and forth head movements [a]

Table 2 (*continued*)

Behavioural Group	Behavioural Subgroup	Definition
Deprivation stereotypy	Pica	Voluntary ingestion of non-food materials
	Coprophagia	Ingestion of faeces
	Uriposia	Drinking urine
Others	Obscured	Most of the individual's body is obscured during observation, making accurate identification of behaviour impossible [a]

[a] Vickery and Mason, 2004.
[b] Hurnik et al., 1995.
[c] Hewish and Zainal-Zahari, 1995.
[d] Liu et al., 2003.
[e] Montaudouin and Le Pape, 2004.

Table 3
Haematologic and serum biochemical profiles of captive *Helarctos malayanus* observed performing coprophagia compared with conspecifics in which the behaviour was not observed (no coprophagia). Values represent mean ± SD. Significant differences ($P < 0.05$) were only detected in the band neutrophils and glucose, as indicated with an asterisk. However, the values for both these parameters were within the range reported for the species.

Parameter	Unit	Coprophagia ($n = 5$)	No coprophagia ($n = 12$)
RBC	$\times 10^{12}$/L	5.50 ± 0.63	5.60 ± 0.62
Haemoglobin	g/L	134.80 ± 15.06	141.33 ± 14.27
PCV	L/L	0.37 ± 0.05	0.39 ± 0.04
MCV	fL	68.20 ± 6.18	70.33 ± 4.01
MCHC	g/L	361.00 ± 13.38	360.75 ± 9.96
WBC	$\times 10^9$/L	9.12 ± 1.77	11.53 ± 2.91
*Band neutrophils	$\times 10^9$/L	0	0.14 ± 0.07
Segmented neutrophils	$\times 10^9$/L	5.70 ± 1.13	7.94 ± 2.51
Lymphocytes	$\times 10^9$/L	2.08 ± 0.83	1.76 ± 0.51
Monocytes	$\times 10^9$/L	0.53 ± 0.17	0.57 ± 0.22
Eosinophils	$\times 10^9$/L	0.74 ± 0.25	1.14 ± 0.56
Basophils	$\times 10^9$/L	0	0
Thrombocytes	$\times 10^9$/L	511.20 ± 91.28	546.17 ± 127.74
Plasma protein	g/L	77.20 ± 6.14	82.83 ± 5.49
Sodium	mmol/L	127.80 ± 4.65	129.58 ± 2.30
Potassium	mmol/L	4.74 ± 0.27	4.88 ± 0.31
Chloride	mmol/L	95.74 ± 5.31	95.01 ± 2.91
Calcium	mmol/L	2.27 ± 0.16	2.44 ± 0.18
Inorganic phosphate	mmol/L	1.71 ± 0.26	1.73 ± 0.22
Urea	mmol/L	5.48 ± 1.85	5.27 ± 2.44
Creatinine	µmol/L	149.00 ± 24.77	142.83 ± 32.85
*Glucose	mmol/L	4.16 ± 0.39	4.98 ± 0.79
Cholesterol	mmol/L	7.35 ± 2.78	8.09 ± 1.71
Total bilirubin	µmol/L	1.24 ± 1.00	1.37 ± 1.12
Alanine transaminase	U/L	36.14 ± 4.51	39.73 ± 16.27
Alkaline phosphatase	U/L	64.60 ± 29.52	59.08 ± 19.60
Gamma-glutamyltransferase	U/L	11.00 ± 5.87	29.75 ± 19.40
Amylase	U/L	503.40 ± 274.38	402.92 ± 250.49
Aspartate aminotransferase	U/L	78.26 ± 13.20	72.37 ± 12.40
Creatine kinase	U/L	115.80 ± 22.41	85.25 ± 45.62
Lactate dehydrogenase	U/L	1321.78 ± 165.97	1045.47 ± 280.69
Total serum protein	g/L	73.60 ± 7.73	77.53 ± 5.16
Albumin (A)	g/L	31.06 ± 4.53	31.10 ± 3.80
Globulin (G)	g/L	42.54 ± 5.11	46.43 ± 4.37
A:G	Unit	0.74 ± 0.11	0.68 ± 0.12
Lipase	U/L	45.67 ± 28.04	33.92 ± 25.22
Uric acid	µmol/L	38.37 ± 4.40	38.99 ± 13.50
Lactate	mmol/L	2.54 ± 0.34	2.63 ± 0.73

RBC – Total red blood cells.
PCV – Packed cell volume.
MCV – Mean corpuscular volume.
MCHC – Mean corpuscular haemoglobin concentration.
WBC – Total white blood cells.

indeed younger than the outdoor bears. This may also explain why the interaction observed among the indoor bears was mainly play-fighting, while contact such as sniffing was the main form of conspecific interaction among the outdoor bears.

The indoor bears spent more time investigating their enclosure environment than did the outdoor bears in both facilities. This finding was contrary to the expectation that the outdoor enclosures, being relatively more furnished, would motivate the bears to spend more time investigating their environment. One possibility would be that these animals had spent many years in the same outdoor environment where changes to the furniture were minimal. In addition, the indoor enclosures were isolated with restricted views of the immediate surroundings. This may have caused the bears to be more inquisitive about what was happening outside their enclosures, and thus, air sniffing and exploratory activity were often observed.

Zoo bears can easily develop begging habits when fed by the public (van Keulen-Kromhout, 1978). This human interactive behaviour was often observed in the outdoor bears in this study. The bears were either standing bi-pedally or sitting with raised

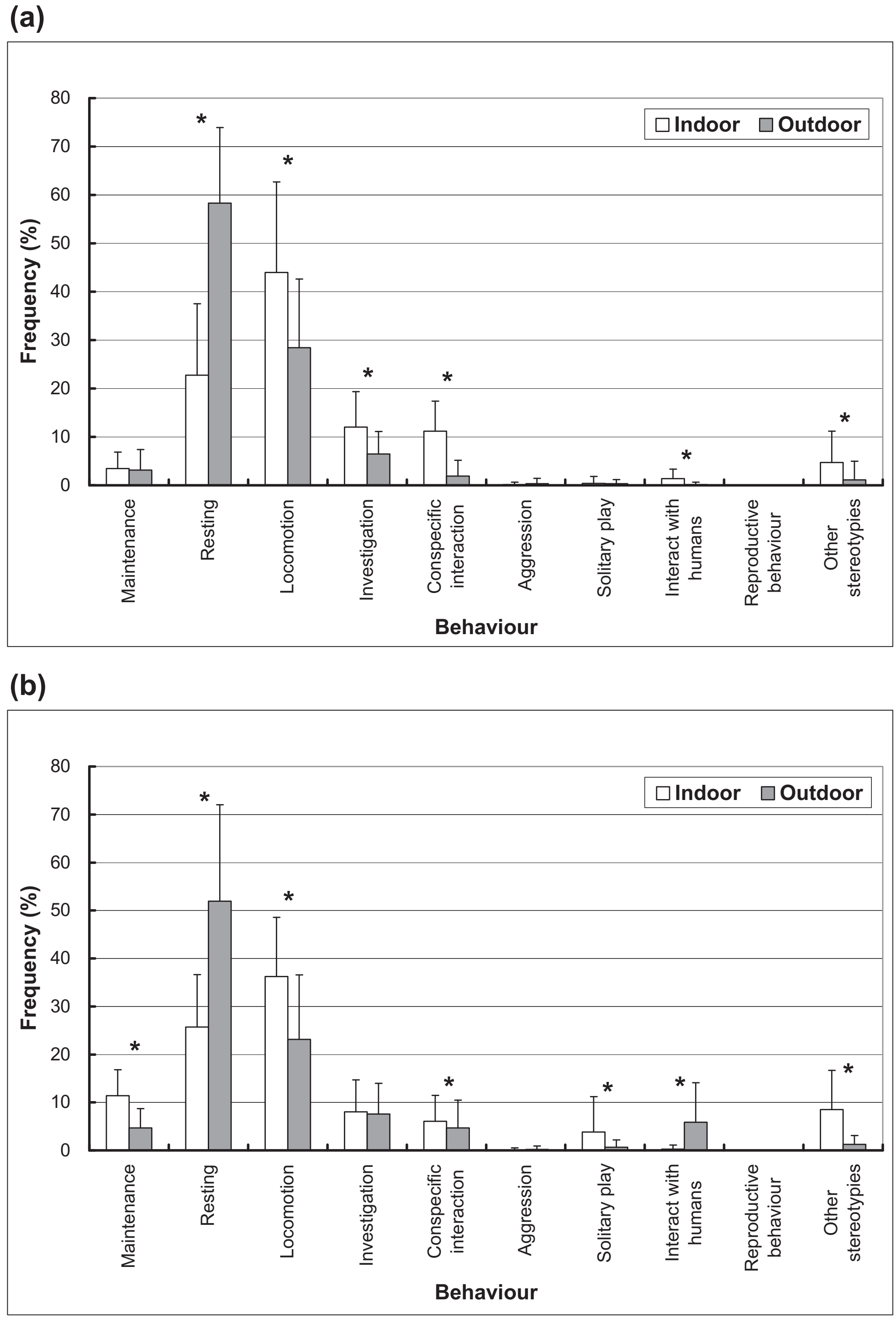

Fig. 2. Diurnal activity budgets of *Helarctos malayanus* housed indoors and outdoors in (a) Zoo-A ($N = 8$) and (b) Zoo-B ($N = 9$). Asterisk above the bars indicates a significant difference ($P < 0.05$) between groups.

forelimbs, often in eye contact with the visitors, with occasional head nodding movements. The frequency of interaction with humans was significantly higher in the outdoor bears in Zoo-B when compared with those in Zoo-A. This is mainly due to the fact that the distance between the visitor location and the animals was closer in Zoo-B. In Zoo-A, interaction with humans was observed more frequent in the bears housed indoors since they were very attentive to the keepers who passed by their enclosures frequently. Conversely, indoor bears in Zoo-B spent more time in solitary play and exhibited a higher frequency of maintenance activity compared with the outdoor bears in the same zoo.

The indoor bears engaged in stereotypic behaviours more frequently, approximately 2.5 times that of their conspecifics housed outdoors. This finding was consistent with a report by Liu et al. (2003) who found that giant pandas housed in a semi-natural enclosure performed less stereotypic behaviours than those in a traditional concrete enclosure. Another study (Jeppesen et al., 2000) also showed that the frequency of stereotypy was higher in farmed mink housed in smaller and traditional cages compared

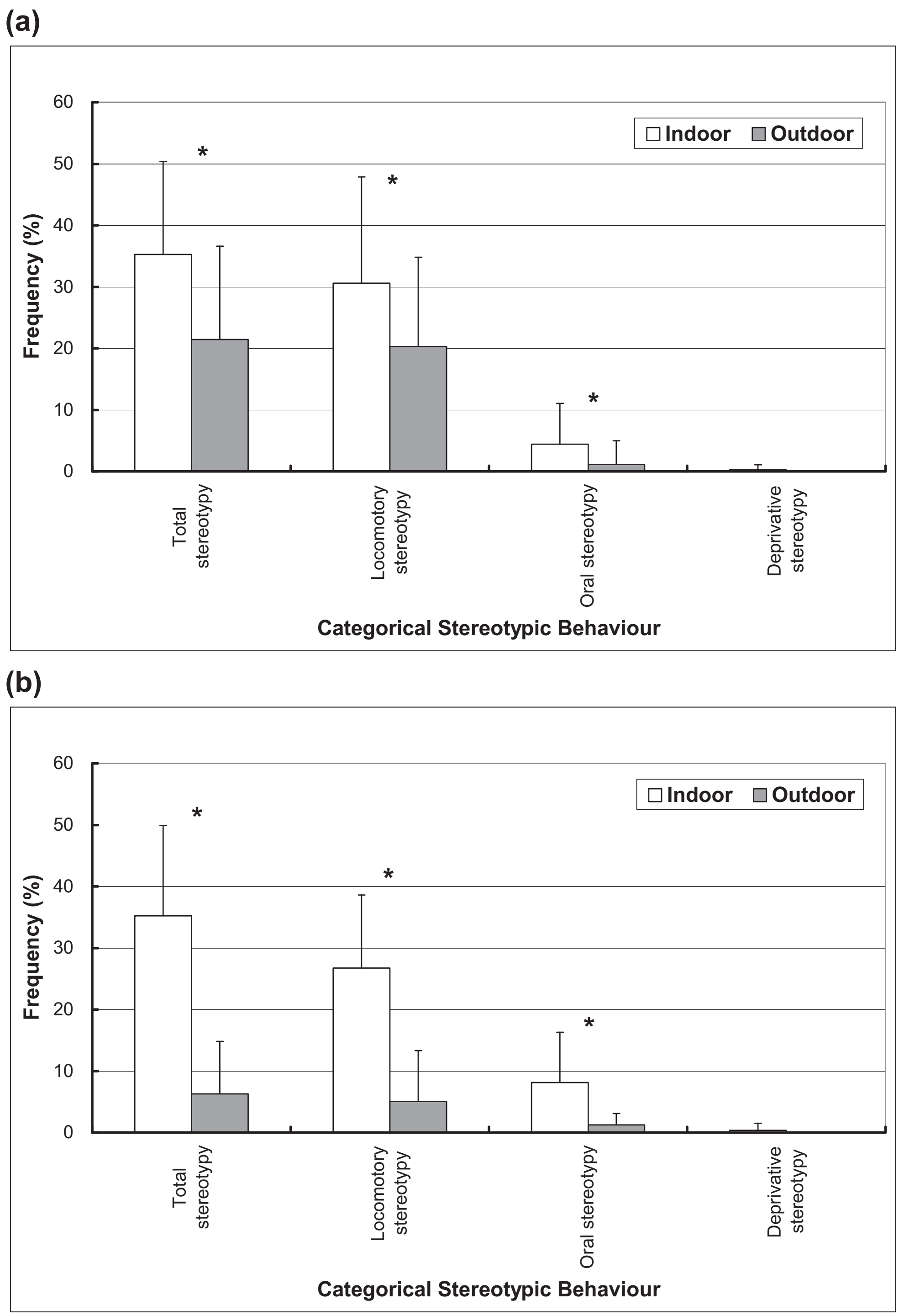

Fig. 3. Frequency of stereotypic behaviours of *Helarctos malayanus* housed indoors and outdoors in (a) Zoo-A ($N = 8$) and (b) Zoo-B ($N = 9$). Asterisk above the bars indicates a significant difference ($P < 0.05$) between groups.

with conspecifics in a more natural environment. Interestingly, Montaudouin and Le Pape (2004) initially cautioned that the proportion of stereotypies exhibited by an animal might not necessarily be related to the housing facilities. However, after further experimentation, they found that bears housed in enclosures with a natural surrounding exhibited lesser stereotyped circling (Montaudouin and Le Pape, 2005). Eleven forms of stereotypic behaviours were observed in this study. Although substantial, the stereotypy behaviours observed in this study were fewer compared with a previous report by Vickery and Mason (2004) who described 25 stereotypic forms in Asiatic black bears (*Ursus thibetanus*) and *H. malayanus*. The predominant form of stereotypy in both enclosure types was pacing which was manifested at a significantly higher frequency in the indoor bears. This behavioural pattern has been shown to be consistent for other carnivores in captivity, whereby the frequency of pacing typically increases as the enclosure size decreases (Carlstead, 1996; Hubrecht et al., 1992; Kreeger et al., 1996). In addition, the reduced complexity of the environment in many captive facilities is known to be associated with increase stereotypic behaviours in a wide repertoire of

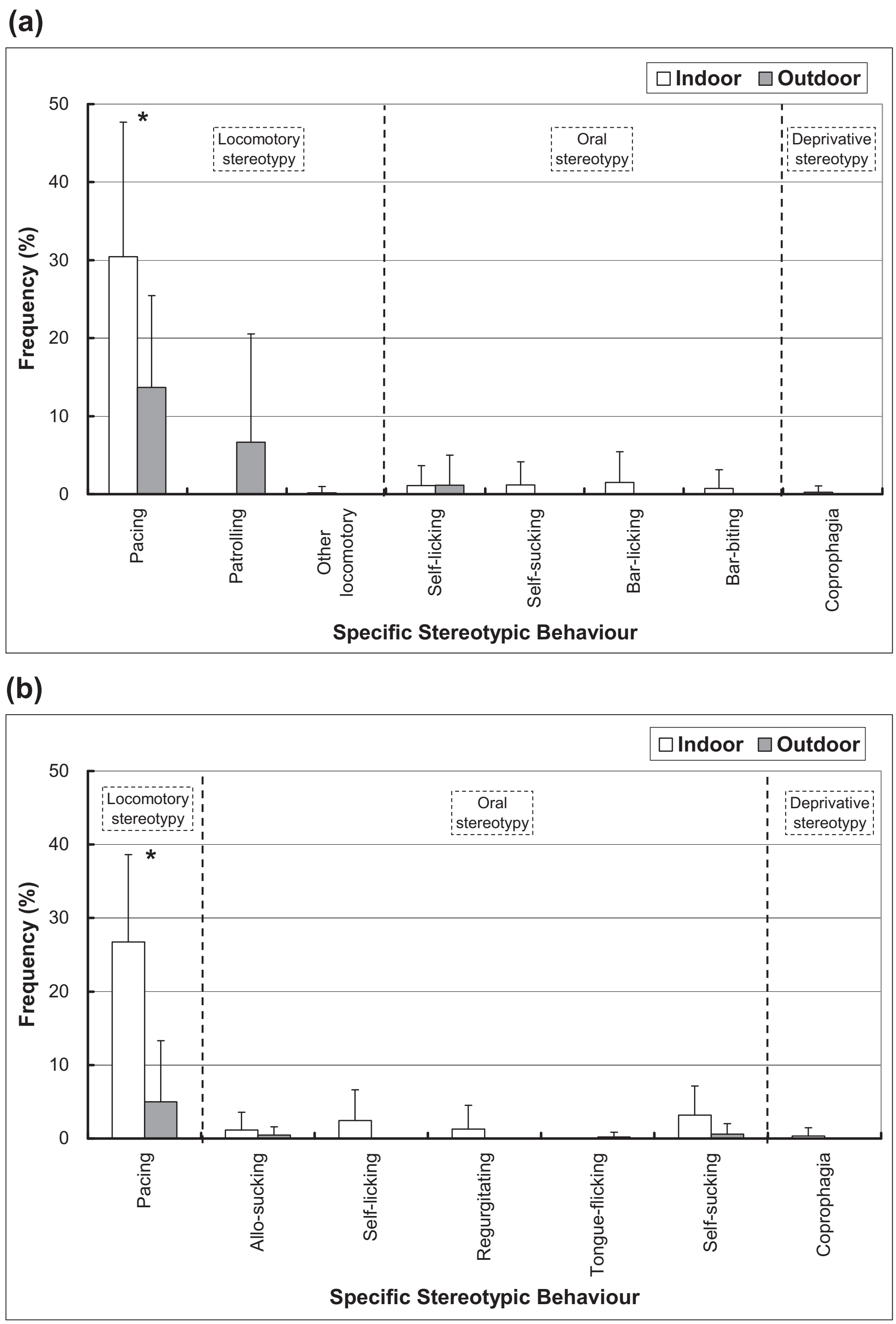

Fig. 4. Frequency of specific stereotypic behaviour of *Helarctos malayanus* housed indoors and outdoors (a) Zoo-A ($N = 8$) and (b) Zoo-B ($N = 9$). Asterisk above the bars indicates a significant difference ($P < 0.05$) between groups.

animals ranging including mice (Würbel et al., 1998; Hadley et al., 2006; Gross et al., 2011), pigs (Von Borell and Hurnik, 1991), carnivores (Lyons et al., 1997; Grindrod and Cleaver, 2001; Mallapur and Chellam, 2002; Brummer et al., 2010), primates (Macedonia, 1987) and birds (Garner et al., 2003). It is also possible that this stereotypic pacing activity pattern may be attributed to anticipatory behaviour for human contact with the keepers or for food (Baldwin, 1985; Bassett and Buchanan-Smith, 2007). It has also been suggested that pacing may be an adaptation to spatial limitations (Hetts et al., 1992; Kreeger et al., 1996) especially if it involves a carnivore species with a wide home range. For smaller carnivores, enclosure complexity appears to be more important than size; Mellen et al. (1998) found less stereotypic pacing in small felids when they were housed in more complex enclosures. Other forms of enclosure enrichment have also been shown to reduce pacing in captive carnivores. Feeding enrichment in the form of hidden food items has reduced locomotor stereotypies in captive bears (Carlstead et al., 1991; Forthman et al., 1992) and leopard cats (Shepherdson et al., 1993). It is interesting to note that the frequency of pacing was similar in the smaller indoor enclosure in

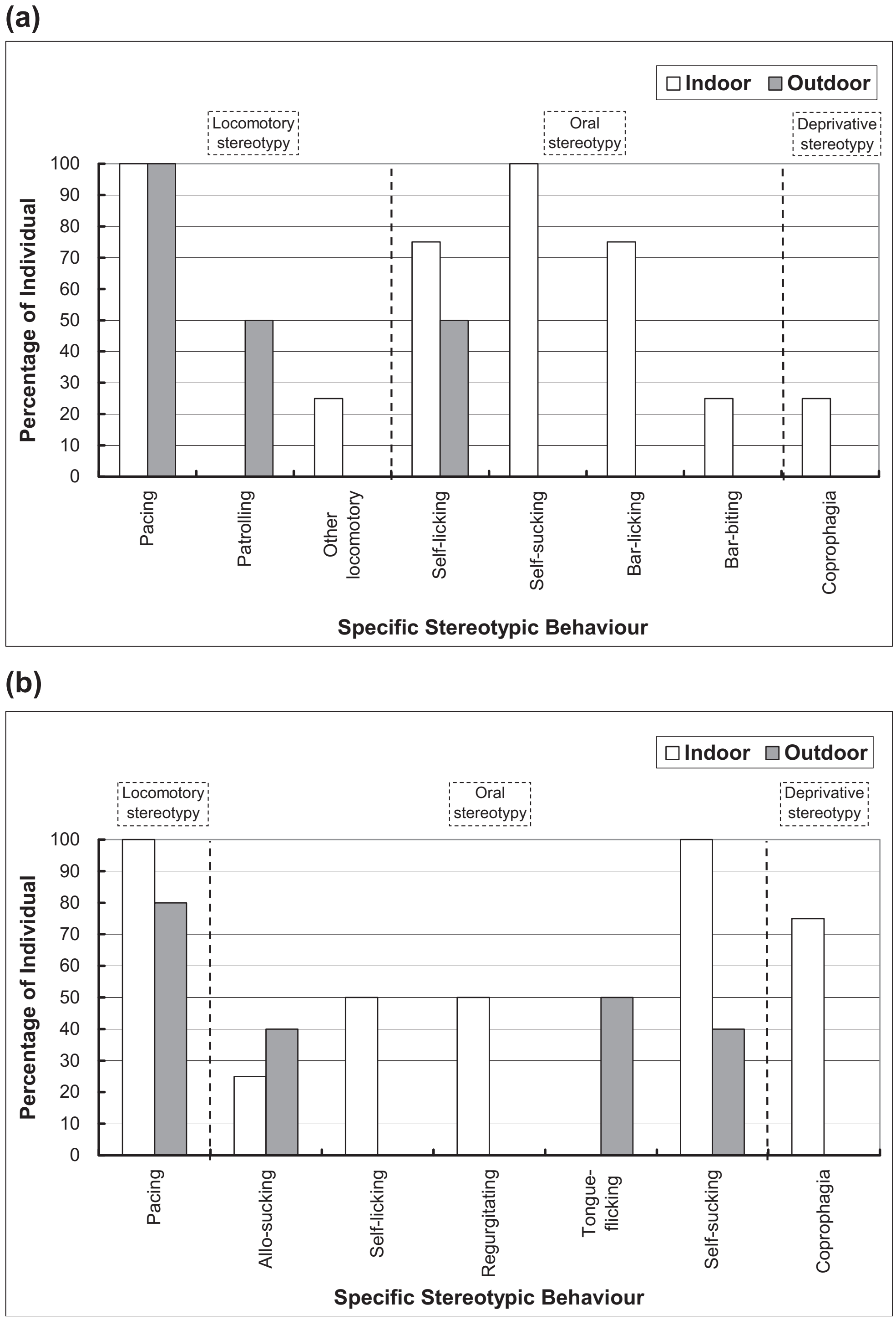

Fig. 5. Percentage of *Helarctos malayanus* exhibiting specific stereotypic behaviours based on their housing conditions in (a) Zoo-A ($N = 8$) and (b) Zoo-B ($N = 9$).

Zoo-B compared to its larger parallel in Zoo-A which was over 2.5 times larger. This is suggestive that the actual size of the enclosure may not significantly influence the frequency or intensity of stereotypies, but the nature and complexity of the environment itself may prove to be fundamental in alleviating abnormal behaviours in captive bears.

Forward-reverse pacing was only observed in a female housed outdoors in Zoo-A. This animal also performed standard pacing. Typically, she would repeatedly move forward and then reverse following the same path without changing her orientation. This is the first report of forward-reverse pacing stereotypy in captive bears, and since this study, we have observed this repetitive behaviour in captive *H. malayanus* in other zoos. Stereotypic patrolling was only observed among the outdoor bears. It is likely that the smaller indoor enclosures did not provide enough space for the indoor bears to perform this behaviour, and it may have been replaced by the high frequency of pacing. Stereotypic patrolling has not been previously described in *H. malayanus* but it is similar to stereotypic circling exhibited by *U. arctos* (Montaudouin and Le Pape, 2005). Patrolling is also a common form of locomotor stereotypy in captive carnivores in many zoological facilities, and well-worn patrolling tracks are easily recognisable in outdoor enclosures with natural substrate.

The bears in this study exhibited seven forms of oral stereotypies, and they were more frequently observed and more diverse in the indoor bears regardless of the feeding time. In a previous study, six forms of oral stereotypy were observed in *H. malayanus* while only one form was found in *U. thibetanus* (Vickery and Mason, 2004). However, the categorization of behaviour was different from the present study, where self-sucking was classified as a form of deprivative stereotypy instead of oral stereotypy. In contrast with the high prevalence of self-sucking in this study, only 17% of the bears in a previous observation (Vickery and Mason, 2004) performed this stereotypic behaviour. The common anatomical sites that the bears sucked were the carpal joints and toes. As previously described, it was often accompanied by a humming vocalization (Dathe, 1975; Vickery and Mason, 2004). Interestingly, some of the oral stereotypies observed in this study such as tongue-flicking and bar-biting were only performed by one or two individuals. The reason for this individualistic repetitive behaviour among captive bears remains unclear, and opens new avenue for psycho-behavioural research in captive animals. Previous studies (Würbel et al., 1996; Nevison et al., 1999; Gross et al., 2011) wave attributed bar-mouthing in mice to escape attempts. It may be possible that the bar-biting behaviour in the captive bears housed in the small and barren indoors cages may reflect a similar behavioural process. An interesting and novel oral stereotypy that was observed in this study was allo-sucking performed by three individuals. It is similar to stereotypic self-sucking, with the only difference being that the animal is sucking on certain body parts of another individual. The preferred anatomical sites of sucking were different among the individual bears; one male sucked the ears of his cage mate, one female sucked the face of the only male in outdoor enclosure, and another female sucked the teats of the other two females. The allo-sucking behaviour of the third bear was actually similar to suckling behaviour seen in young animals. Although this bear was 10 years old, she was the youngest in the group and may have maintained this behaviour since. The precise reason for the occurrence of allo-sucking in captive *H. malayanus* cannot be explained with certainty at the present moment. It may be possible that this behaviour is related to attention seeking, frustration or may be analogous to “non-nutritive” allo-suckling reported in veal calves (Luescher et al., 1989). The exact aetiology of this form of oral stereotypy in captive bears however, requires further investigation before any concrete inferences can be made.

Coprophagia was the only deprivative stereotypy observed in this study and it was only apparent in the indoor bears. The faecal material ingested included those from themselves and their cage mate. Since indoor bears were kept in concrete-floored enclosures, deficiency in minerals may have contributed to this behaviour. However, the haematologic and serum biochemistry values for the bears were well within the range reported for the species (Stuhrberg, 1988; Ramsay, 2003; unpublished reference data, Clinical Pathology Laboratory, Faculty of Veterinary Medicine, Universiti Putra Malaysia), with the exception of six bears that had slight decrease in sodium (two performing coprophagia, four not performing coprophagia) and three with slight elevations in cholesterol (one performing coprophagia, two not performing coprophagia). The lower values for band neutrophils and glucose observed in the bears performing coprophagia compared with the conspecifics that did not engage in this activity, may be an artefact of the small sample size and may not have a direct influence on coprophagia. In addition, values for both these parameters in all the bears were within that reported for the species. It is interesting to note that bears performing coprophagia showed lower serum glucose levels. Since the diet of the captive bears consists predominantly of ripe fruits, bread and milk, the partially digested faecal material may still be high in sugars and other nutrients. This may attract the bears with lower glucose levels to re-consume the faeces. However, due to the small sample size examined, this remains a speculation and must await further detailed investigation on a larger array of captive animals before any concrete relationship between coprophagia and serum biochemistry values can be proposed. Vickery and Mason (2004) previously suggested that coprophagia is a form of compulsive behaviour in *H. malayanus* and *U. thibetanus*, and therefore may not be related to nutritional deficiencies.

The present body of evidence strongly suggests that enclosure complexity plays a pivotal role in determining activity budgets and the occurrence and frequency of abnormal repetitive behaviours in captive Malayan Sun bears. As such, any attempts to keep these animals for the purpose of conservation and breeding, must first address the appropriateness of the enclosure environment in order to ensure that stress levels are minimal and the overall welfare of the animals are not compromised.

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