

# Stereotypic Behavior in Asiatic Black and Malayan Sun Bears

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The stereotypies of individually caged Asiatic black bears (*Ursus thibetanus*) and Malayan sun bears (*Helarctos malayanus*) were studied in detail. Stereotypies were performed by 27 of the 29 subjects, were primarily locomotory in form (e.g., pacing), and occupied on average 18% (standard error of the mean (SEM) = 2.5) of daylight hours. Stereotypy levels during the night were almost negligible and were highly correlated with daytime levels. Total stereotypies peaked prior to food arrival, although oral stereotypies were most frequent after feeding. In general, stereotypies were performed in locations from which food arrival could be viewed, although Asiatic black bears were equally likely to exhibit stereotypy near a neighboring bear. Across individuals, stereotypy frequency was inversely correlated with inactivity and increased with age. Older bears also showed less normal activity and a reduced diversity of normal behavior. Stereotypy levels were unrelated to levels of “compulsive” behavior (e.g., hair plucking) or repetitive self-sucking—a potential deprivation stereotypy. More frequent stereotypies were performed more invariantly (i.e., were more predictable from one repetition to the next) and in more diverse contexts, namely 1) outside the pre-feeding period, and 2) during the night. Contrary to observations reported elsewhere, higher frequencies of stereotypy were not associated with reduced behavioral diversity, or with a more elaborate repertoire of stereotypy forms and sequences. Although the two species did not differ in overall frequency, the stereotypies of sun bears appeared to be more food-motivated than those of Asiatic black bears: the sun bears displayed a higher frequency and diversity of oral stereotypies, and higher levels of pre-feeding stereotypy, and performed significantly more of their total stereotypies in locations from which they could view food arrival. This study demonstrates how analyzing stereotypies in detail can help identify the motivations that underlie these behaviors, and potentially reveal their degree of establishment—both of which are important factors in stereotypy treatment. Zoo Biol 23:409–430, 2004. © 2004 Wiley-Liss, Inc.

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## INTRODUCTION

Stereotypies are invariant in style, performed repetitively, and appear to have no function [Ödberg, 1978; Mason, 1991a]. Common in a range of animal species and husbandry systems, they are of concern primarily because of their association with poor welfare [reviewed by Mason, 1991b; Mason and Latham, 2004], but also because they often have negative consequences (for example, on health [e.g., Fraser and Broom, 1990]). For zoos, stereotypies represent a further problem in that they may be detrimental to conservation efforts [e.g., Shepherdson, 1994; Vickery and Mason, 2003] and visitor education [Carlstead, 1998], and may also attract criticism from the public and animal welfare organizations [Fielding, 2001].

Captive bears appear to be particularly susceptible to stereotypies. In a survey of stereotypies in 33 carnivore species, ursids displayed both the highest frequency (i.e., proportion of observed time) and maximum prevalence (i.e., percentage of individuals affected) compared to other families (e.g., canids and felids) [Clubb, 2001]. Studies of stereotypies in bears have documented a wide range of forms. Pacing appears to be the most common stereotypy, and is performed along straight routes, in circles, or in figure-eights [Meyer-Holzappel, 1957; Ames, 1994, 2000; Langenhorst, 1998]. However, other behaviors, such as weaving, head-swaying, stereotypic swimming, and tongue-flicking [Meyer-Holzappel, 1968; Fox, 1971; Wechsler, 1991; Kolter and Zander, 1995; Hennessy, 1996; Ames, 2000] have also been reported. Individual frequencies are highly variable: some bears display no stereotypy at all [e.g., Tepper et al., 1999], while others may exhibit stereotypy for up to 77% of observed time [Wechsler, 1991]. Individual variation is often high even within a species [Ames, 1994, 2000], and has been linked with variation in behavioral persistence [Vickery and Mason, 2003] (Vickery and Mason, unpublished results). Other properties of bear stereotypies are less commonly assessed, and our ability to draw general conclusions is further hampered by variations in methodology, husbandry, and individual factors. However, broadly speaking, bear stereotypies appear to be highly invariant (i.e., their movements are very predictable from one repetition to the next). For example, in a study of pacing in three polar bears, Wechsler [1991] reported that “at a given place an equal number of steps is repeated over and over, the paws regularly touch the ground on the same spots, and the duration of a lap hardly varies [p 187].” They also tend to be performed in highly specific areas [Langenhorst, 1998] and to peak before feeding [Langenhorst, 1998; Landrigan et al., 2001].

Many studies have attempted to alleviate bear stereotypies, usually by enrichment [Carlstead et al., 1991; Forthman et al., 1992; Fischbacher and Schmid, 1999; Swaisgood et al., 2001], but also with the use of homeopathic [Jordan-Owers, 2003], anti-depressant [Poulsen et al., 1996, 1998], and anti-psychotic [Uchida and Dodman, 1998] drugs. However, despite the focus on reducing these behaviors, few studies on bears have examined stereotypies in any depth. Indeed, of 36 studies that quantitatively assessed stereotypy in zoo-housed bears (90% of which attempted to reduce stereotypy (see Vickery [2003] for details), most (58%) quantified only the

frequency, and made no reference to the behavior's invariance, timing, or location-properties that could offer clues to the stereotypy's motivational basis and degree of establishment [Mason, 1993a; Carlstead, 1998; Vickery and Mason, 2003b]. Therefore, it seems that in their haste to alleviate these behaviors, zoo keepers have actually spent little time on trying to understand them.

Perhaps because of this, many gaps exist in our knowledge of bear stereotypy. For example, we do not know whether bears perform stereotypies at night, why certain locations are preferred, why stereotypies differ in form, how they develop over time, or how they impact on general behavior. In some cases we can make predictions based on studies of other species. For example, previous studies have shown that animals exhibit stereotypies in areas where they can detect something they crave, such as food or escape [Mason, 1993a; Lyons et al., 1997; Nevison et al., 1999], and/or areas that offer high levels of sensory stimulation [Roynon, 2000, cited in Knowles and Plowman, 2001]. Developmental studies of laboratory rodents, and farmed pigs and mink, have shown that stereotypy increases in frequency with age and/or time spent in captivity [Cronin and Wiepkema, 1984; Cooper and Ödberg, 1991; Terlouw et al., 1991; Mason, 1993a; Würbel et al., 1996]. It has been observed in mink studies that the most frequent stereotypies are also performed the most invariantly [Mason, 1993a; Clubb, 2002], a finding consistent with many developmental theories of stereotypy [e.g., Fentress, 1976, 1977]. In some species, the number of different stereotypies performed, and the sequence complexity appear to increase with increasing frequency and/or age, although the forms themselves may become abbreviated [Goosen, 1981; Cronin and Wiepkema, 1984; de Jonge et al., 1986]. Furthermore, later in their development, stereotypies may be elicited by stimuli that did not trigger them during earlier stages—for example, by generally “arousing” stimuli such as loud noises [Berkson and Saxon, 1963; Lukas, 1999]. In this way, stereotypies may come to be performed in more diverse situations [Cronin, 1985]. They are then termed “emancipated” because they appear to be divorced from their original underlying motivation [Ödberg, 1978; Cooper and Ödberg, 1991]. However, such features have not been well studied in terms of bear stereotypies, and since even closely related strains of the same species can differ quite radically in their expressions of stereotypy [e.g., Würbel et al., 1996], there is some risk in assuming that what is true for a laboratory rodent or farmed pig is equally true for a zoo-housed carnivore.

Therefore, in this paper we present a detailed analysis of the behavior of captive Asiatic black bears (*Ursus thibetanus*) and Malayan sun bears (*Helarctos malayanus*), two ursid species that have been the subject of disproportionately few behavioral studies. We assessed the properties of the bears' stereotypies to supplement the somewhat patchy information currently available, to test hypotheses concerning stereotypy development, and to better understand their motivational bases.

## **MATERIALS AND METHODS**

### **Animals and Housing**

Observations were carried out on 29 bears (18 Asiatic black bears (7.11) and 11 Malayan sun bears (5.6)) housed in a government wildlife facility in Thailand. The bears ranged in age from approximately 1.5 to 11 years (the ages were approximated

on the basis of center records), and most ( $n = 26$ ) were adults ( $> 3$  years old). All were wild-born, but had been poached as cubs for illegal wildlife trafficking and later confiscated by the Thai Royal Forest Department. The exact age at which the bears were taken from their mothers is unknown, but many were probably taken before they were fully weaned. The ages and lengths of time in captivity are thus almost perfectly confounded.

The bears were individually and identically housed in  $5 \times 4 \times 3$  m (L  $\times$  W  $\times$  H) concrete-floored cages. A covered den, to which access was constantly available, measured  $2 \times 4 \times 3$  m and contained a bench for resting. The cages were arranged in pairs, and furnished with logs and tires for enrichment. Other forms of environmental enrichment were offered occasionally and irregularly. The bears were fed a single meal of rice, chicken, and fruit between 1500 and 1600 hr, Monday through Saturday, and between 0700 and 0730 hr each Sunday (the data presented here are for Monday–Saturday only). Water was available ad libitum from water nozzles in the main cage section. The facility was closed to the public.

### Data Collection

Data were collected over five periods spaced over  $\sim 2$  years (Table 1). Behavior was assessed by scan-sampling [Martin and Bateson, 1993] from observation hides between the cages. Pilot studies confirmed that such data were comparable to data obtained from video recordings (i.e., the bears were unaffected by the scanning method) [Vickery, 2003]. For each scan, the hides were visited in a predetermined order, and each bear's behavior was recorded by instantaneous sampling. A complete scan of all individuals took 9–19 min depending on the number of bears involved, and up to 43 scans (5–8 hr each) were completed daily. All scans were evenly distributed between 0700 and 1800 hr.

Behaviors were classified as 1) normal, 2) stereotypic (e.g., pacing or weaving), 3) compulsive (defined as nonrepetitive, apparently functionless behaviors that are self-directed and/or bizarre, e.g., self-biting and hair-plucking), and 4) repetitive self-sucking (sometimes accompanied by a “humming” vocalization). In the present study this latter behavior was considered a “deprivation stereotypy” [e.g., Ridley and Baker, 1982] on the basis that in bears it apparently is exclusive to very early-weaned individuals [van Keulen Kromhout, 1976; Hawes, 1997] (Molloy, unpublished results; Maas, unpublished results), it resembles normal suckling by

**TABLE 1. Details of behavioral assessment periods**

Study year	Calendar year	Dates of assessment period	Number of observation days	Mean number of scans per bear per day	Number of bears observed
1	2000	June 1st–30th	25	24.3	16
	2000	November 21st–29th	8	25.8	9
	2001	February 7th–17th	9	28.2	15
2	2001	November 15th–December 9th	19	20.8	18
	2002	February 25th–March 8th	9	27.8	17

bear cubs [Davids, 1982], and it is similar to behaviors seen in isolation-reared primates and other early-weaned mammals [Richter, 1925; Cross and Harlow, 1965; de Passille and Rushen, 1997]. See Table 2 for a full ethogram of behaviors.

Stereotypes were watched for up to three repetitions of the behavior or sequence (i.e., a commonly repeated chain of movements, such as “pacing – head-dipping – pacing – head-rearing”), and were termed “Invariant” when three successive identical repetitions (with or without pause) were observed. Cage location was also recorded for all stereotypes.

During an additional assessment period (April 2001), nocturnal data were collected from 2000 to 0600 hr for 14 bears (eight Asiatic black bears and six sun bears). Since it was not possible to conduct full scans in the dark, a maximum of four bears were observed each night from a single hide. The behavior of each was sampled every 15 min with the use of night-vision binoculars (model BN5; Newcon, Toronto, Canada).

### **Statistical Analyses**

To control for seasonal differences, we pooled the data collected over the five assessment periods, with the exception that for bears studied during years 1 and 2 ( $n = 7$ ), means were calculated from year 1 data only, so that an age could be specified for each data set.

We analyzed the data to examine the effects of age, species, sex, and context on the bears' stereotypes, and to look for relationships between stereotype frequency and other behavioral measures. Whenever possible, ANOVAs and parametric regression analyses were used for data analysis, and were performed with the use of general linear models (GLMs; Minitab 12, Minitab Inc., PA, USA) so that other variables could be statistically controlled for when necessary, and categorical and continuous variables could be combined. Nonparametric statistics were used when the assumptions of parametric testing were not upheld, and no appropriate transformation could be found.

### **Properties of Stereotypy**

#### *Frequency*

Stereotypy frequency (i.e., the number of scans in which stereotype was observed as a proportion of all scans made) was tested for effects due to age, species, and sex. The frequencies of stereotype performed during a 2.5-hr period immediately prior to feeding (hereafter termed “pre-feed”) were compared with frequencies during an equivalent period after food delivery (“post-feed”). Observations of feeding and normal activity were statistically controlled for to ensure that any changes in stereotype frequency were not artifacts of increased feeding or reduced normal activity in the post-feed period. We also calculated frequencies of stereotype outside the pre-feed period to test whether bears with arguably more established stereotypes (as indicated by age, stereotype frequency, and/or variability) performed them in more diverse situations (i.e., outside the most “usual” time).

#### *Form*

Stereotypes were categorized as 1) locomotory forms, involving walking or running (e.g., pacing); 2) oral forms, involving movements of the tongue or jaw (e.g., sham-chewing); and 3) other forms, i.e., movements falling outside the

**TABLE 2. Full ethogram of normal, stereotypic, and compulsive behaviors observed during the study**

Normal stance and locomotor activities	Sitting or lying with body motionless for at least 30 sec and/or eyes closed; does not appear alert.
Rest, drowsy/asleep	Sitting or lying with eyes open; appears alert.
Rest alert	Bi-pedal or quadrupedal stationary stance.
Stand	Move from one location to another at floor level by walking or running.
Locomote	Pause of less than 5 sec duration during locomotion. (Pauses of 5 sec or more are classed as "stand".)
Pause	Any change between the stances: lie, sit, and stand at floor level.
Change stance	Stand or locomote above floor level with no body weight supported by the cage floor.
Climb	
Normal behaviors	
Feed	Ingestion of edible material.
Drink	Consumption of water.
Eliminate	Defecation and urination.
Maintenance	Any nonstereotyped maintenance activity (e.g., scratch, rub, lick, shake), stretch any part of body and swat at flies on body).
Manipulate cage	Any nonstereotyped manipulation (e.g., lick, bite, grasp, chew, scratch) directed at the cage structure or permanent apparatus.
Manipulate water nozzles	Any nonstereotyped manipulation of water nozzles for purposes other than drinking.
Manipulate food items	Any nonstereotyped manipulation (but not actual ingestion) of edible food materials.
Manipulate other items	Nonstereotyped manipulation of previously uncategorized items (e.g., coconut husks, feathers).
Sniff ground or object	Sniffing cage floor or object attentively for a period of more than 5 sec.
Sniff air	Sniffing air attentively for a period of more than 5 sec.
Neighbor interaction	Behavior directed at bear in the adjacent cage. Sub-categories are affiliative, neutral, and agonistic.
Auto-play	Energetic and exaggerated play movements that may or may not involve objects.
Other	Any nonstereotyped behavior not falling into one of the above categories.
Stereotypic behaviors	
Locomotor stereotypies	
Standard pace	Locomotion (straight ahead) along a full cage length; body aligned with cage bars or wall and head held centrally.
Extended pace	As "Standard pace" but pace exceeds one cage length.
Standard weave	Locomotion (to left and right alternately) with body perpendicular to cage bars or wall; front feet occupy two or more positions; rear feet may be lifted and repositioned or only shuffled.
Short weave	As "Standard weave" but front feet occupy only one definite position and may hover over a second.
Weave with steps	Standard or short weaving movements interspersed with back and forth movements so that the body traces a T-shape.
Loop	Locomotion (straight ahead) tracing a circular or elliptical route.
Steps	One or two steps (to left and/or right) taken in conjunction with "head sway".
Head throw	Throwing head back and over shoulder during locomotion (straight ahead) tracing a diagonal path across the cage.

Turning movements and elements used only in conjunction with pace	
Head rear	Muzzle angled up; all feet remain on ground.
Head dip	Muzzle angled downwards and bows towards cage floor.
Head scoop	Head reared and dipped in a single movement; may also be shaken at base of dip.
Body rear	Head and upper body reared; front feet are lifted off ground.
Body flop	Head and upper body reared and fall in a collapse-like movement.
Water bath	Water bath stepped up onto or sat upon.
Oral stereotypies	
Tongue flick	Tongue is flicked in and out of mouth.
Tongue curl	Tongue is extended and curled up and around muzzle.
Jaw clamp	Teeth are clamped together repetitively.
Sham chew	Jaws are moved as though food is being chewed but the mouth is empty.
Self-lick	Repetitive licking of a body area (distinguished from "excessive manipulation" by the invariance and repetition of movements).
Retch food	Food taken into the mouth, chewed, and retched onto a paw or cage surface repeatedly (differs from regurgitation and reingestion in that the food doesn't reach the stomach between repetitions).
Other stereotypies	
Head sway	Body positioned as in "short weave" but primary movement is a pendulum-like swaying of head with eyes directed at cage floor; front feet touch the ground at only one definite position.
Head lean	Head smoothly leaned far back over shoulders without throwing action.
Head circle	Head rotated in a circular fashion.
Hopping	Body positioned as in "short weave" but weight is transferred back and forth between the front feet in a hopping motion.
Claw grate	Claws of front feet are rasped together producing a grating noise.
Deprivation stereotypies	
Self-suck	Repetitive sucking of a body area, often accompanied by a distinct 'humming' vocalization.
Compulsive behaviors	
Self-directed aggression	Biting, slapping, grasping, or aggressively pulling at own body, usually the head or rear legs.
Excessive body manipulation	Excessive, but nonaggressive manipulation of body areas (e.g., over-grooming, hair plucking, and excessive nibbling or licking).
Bar lick	Tongue is held against cage bars for an extended period of time (usually > 30 sec); edge of tongue may be curled around or pressed up against bars.
Foam	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.
Coprophagy	Eating of own feces.
Urine drinking	Drinking of own urine.
Other	
Out-of-sight	Bear is in the den.
Obscured	The majority of the bear's body is obscured making accurate identification of behavior impossible.

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previous categories (e.g., head-swaying). Some (e.g., head-rearing) were performed only during pacing sequences (usually to reverse the direction of locomotion) and were never observed by themselves. These were termed stereotypic “elements,” and were categorized as locomotory. The frequency with which bears exhibited each type was calculated as a proportion of total stereotypy. Frequencies were also calculated for the pre- and post-feed periods separately, for comparison. For each bear, the total number of different forms and sequences performed was also calculated.

### *Variability*

The proportion of total stereotypy categorized as “Invariant” was calculated for each bear that had 10 or more observations of stereotypy per assessment period (equivalent to Mason’s [1993a] “rigidity index”). Previous analyses [Vickery, 2003] showed that this measure is in part influenced by the duration of a given form of stereotypy: short-duration stereotypies (e.g., head-swaying) are more likely to be scored as “Invariant” than longer forms (e.g., pacing) simply because they are less likely to be interrupted mid-cycle. To control for this, the mean duration of each bear’s main form of stereotypy (one complete repetition) was measured and included as a covariate in analyses involving variability. Stereotypy variability was tested for effects due to age, species, sex, and stereotypy frequency.

### *Timing*

We calculated the mean stereotypy frequencies for each observation hour (0700–1800 hr) to plot temporal patterns and test for species differences. Stereotypy frequencies during the night were tested for a correlation with daytime levels. We also looked for differences in age and daytime stereotypy frequency between bears that did and did not perform stereotypies at night.

### *Location*

Stereotypy location was assessed for all bears that had 10 or more observations of stereotypy per assessment period, and whose main or sole stereotypy was not circular pacing (a form involving all cage sides equally). Each bear’s main cage area was bordered by four sides, which were classified as 1) “Front,” a 3-m length of barred cage with an external door fitting; 2) “Back,” a 3-m length of barred cage opposite of the “Front”; 3) “Adjacent,” a 4-m length of barred cage shared with a neighboring cage (which may or may not have housed another bear, and was termed “Adjacent-neighbor” and “Adjacent-empty,” respectively); and 4) “Wall,” a 4-m length of cage consisting of a solid cement wall.

The cage sides that were associated with 1) the first view of food arrival (variable across bears, depending upon cage location), and 2) contact with a neighboring bear (“Adjacent-neighbor”) were hypothesized to be most frequently associated with stereotypy. In contrast, the cage sides that offered low sensory stimulation (i.e., the cement wall (“Wall” for all bears), and adjoining empty cages (“Adjacent-empty”)) were predicted to be less frequently used for stereotypy. To test this, we identified the cage sides associated with these factors for each bear, calculated the proportion of all stereotypies that occurred along each side, and then compared for the two species separately using Mann-Whitney tests. We adjusted the

accepted  $P$ -values to control for multiple testing using the Hochberg step-up procedure [Hochberg, 1988].

### Other Behaviors

We calculated the frequencies of normal activity, inactivity, compulsive behavior, and repetitive self-sucking to test for relationships with stereotypy frequency, age, species, and sex.

Using data collected during each bear's longest assessment period, we calculated normal behavioral diversity using the Shannon-Wiener function "H" [Shannon and Weaver, 1949]. With this index, a greater number of behaviors and/or a more even distribution among behaviors acts to increase the index value, with higher values of H representing greater behavioral diversity. Effects of age, species, sex, and stereotypy frequency on behavioral diversity were looked for.

## RESULTS

### Properties of Stereotypy

#### *Prevalence and frequency*

Stereotypy was highly prevalent, being exhibited by 27 of the 29 bears. Frequencies ranged between 0 and 51% of all observations (mean = 18%; standard error of the mean (SEM) = 2.5), and were unaffected by species or sex. However, older bears exhibited higher frequencies (GLM:  $F_{1,24} = 7.59$ ;  $R^2 = 52\%$ ;  $P = 0.011$ ), and this relationship held when levels of normal activity were statistically controlled for (GLM:  $F_{1,24} = 7.37$ ;  $R^2 = 35.2\%$ ;  $P = 0.012$ ; Fig. 1). Frequencies of stereotypy were significantly higher during the pre-feed period than the post-feed period (statistically controlling for frequencies of feeding and normal activity; GLM:  $F_{1,25} = 11.09$ ;  $P = 0.003$ ). Neither a bear's age nor the variability of its stereotypy predicted its level of stereotypy outside the pre-feed period. However, there was a trend for overall stereotypy frequency to explain this measure: bears with higher total frequencies performed a greater proportion of their stereotypy outside the pre-feed period (GLM:  $F_{1,19} = 3.68$ ;  $R^2 = 47.3\%$ ;  $P = 0.070$ ).

#### *Form*

Twenty-five stereotypic forms or elements were observed (see Table 2). Across all bears, locomotory stereotypies were significantly more frequent than oral or other forms (Kruskal Wallis:  $H = 45.65$ ;  $DF = 2$ ;  $P < 0.001$ ), and comprised 81% of all stereotypies. As a proportion of total stereotypies, the frequencies of locomotory forms did not differ between the two species; however, Asiatic black bears displayed higher frequencies of stereotypies categorized as "other" (mean = 27.4% of total stereotypy, compared to 2%; Kruskal Wallis:  $H = 6.52$ ;  $DF = 1$ ;  $P = 0.011$ ), while sun bears performed higher frequencies of oral stereotypy (mean = 0.7% of total stereotypy, compared to 0.03%; Kruskal Wallis:  $H = 4.79$ ;  $DF = 1$ ;  $P = 0.029$ ). The sun bears also performed a greater number of different oral stereotypies (six forms) compared to the Asiatic black bears (one form).

The average individual repertoire included three (SEM = 0.4) stereotypic forms or elements. This number did not relate to stereotypy frequency, age, or sex, but the sun bears displayed significantly more forms than the Asiatic black bears (4.8 vs. 1.6,

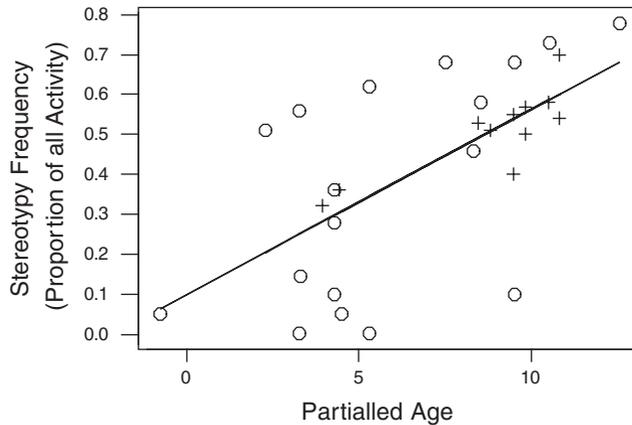


Fig. 1. Regression relationship between stereotypy frequency (as a proportion of all activity) and age (statistically controlled [“partialled”] for sex and species), for Malayan sun bears (crosses,  $n = 11$ ) and Asiatic black bears (circles,  $n = 18$ ).

respectively; GLM:  $F_{1,27} = 16.2$ ;  $P < 0.001$ ). In the average repertoire these forms were combined into two (SEM = 0.3) stereotypic sequences, and again the number of sequences exhibited was not predicted by stereotypy frequency, age, or sex. However, the sun bears performed more sequences than the Asiatic black bears (3.6 vs. 1.2, respectively; GLM:  $F_{1,27} = 13.46$ ;  $P = 0.001$ ). Across both species, the proportion of stereotypy that comprised locomotory and “other” forms did not differ between the pre- and post-feed periods, but frequencies of oral stereotypy were significantly higher after feeding (Mann-Whitney:  $W = 624.5$ ;  $DF = 1$ ;  $P = 0.048$ ; Fig. 2).

### Variability

The proportion of stereotypy categorized as “Invariant” differed greatly across bears, but was not explained by age, species, or sex. However, frequency did predict variability, with the most stereotypic animals performing higher proportions of “Invariant” stereotypy (GLM:  $F_{1,18} = 4.79$ ;  $R^2 = 44.2\%$ ;  $P = 0.042$ ; Fig. 3).

### Timing

All of the bears showed similar temporal patterns of stereotypy (Fig. 4a and b): a morning peak, a main pre-feeding peak (more pronounced in sun bears), and a rise toward the end of the day. When the time of day was controlled for, species differences in stereotypy frequency were only significant between 1400–1500 hr (i.e., during the pre-feeding peak), when the sun bears’ levels were highest (GLM:  $F_{1,24} = 25.79$ ;  $P < 0.001$ ). Nocturnal frequencies of stereotypy were very low (mean = 1.9%;  $n = 14$ ; SEM = 1.0), and positively correlated with a bear’s level of daytime stereotypy (GLM:  $F_{1,12} = 32.8$ ;  $R^2 = 73.2\%$ ;  $P < 0.001$ ). Bears that exhibited stereotypy during the night ( $n = 5$ ) had higher levels of daytime stereotypy than those that did not ( $n = 9$ ) (Kruskal Wallis:  $H = 6.6$ ;  $DF = 1$ ;  $P = 0.010$ ), and there was also a trend for these bears to be older (Kruskal Wallis:  $H = 2.92$ ;  $DF = 1$ ;  $P = 0.087$ ).

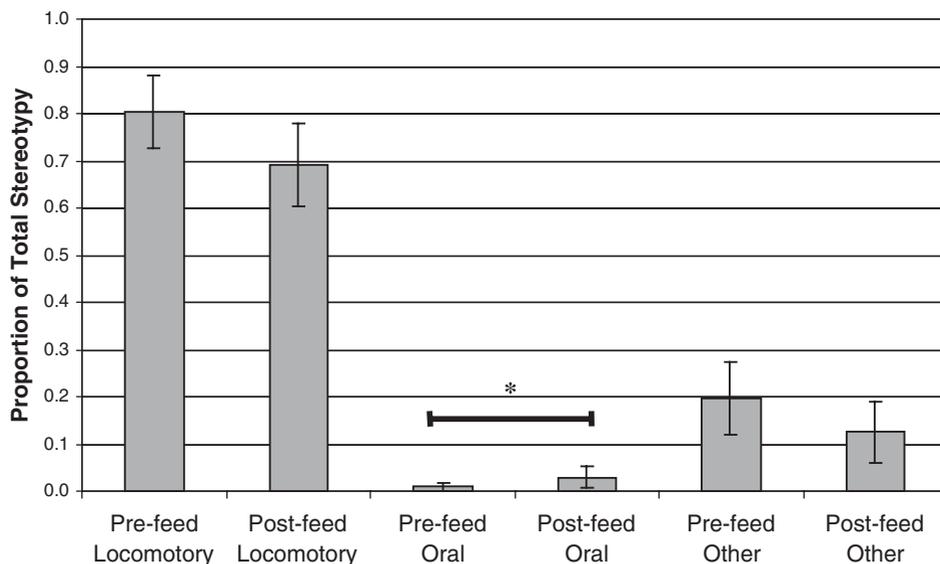


Fig. 2. Frequencies of locomotory, oral, and other stereotypies as a proportion of all stereotypies performed during a 2.5-hr period immediately prior to feeding (“pre-feed”) and an equivalent period after food delivery (“post-feed”). \* $P < 0.05$ .

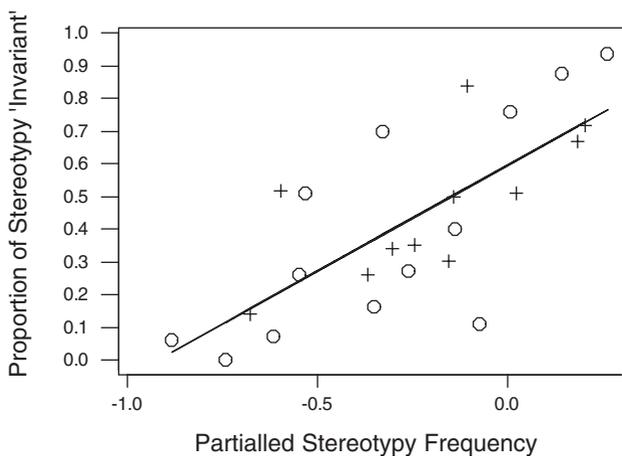


Fig. 3. Regression relationship between stereotypy frequency (statistically controlled [“partialled”] for sequence duration, sex, and species) and the proportion of stereotypy categorized as “Invariant,” for Malayan sun bears (crosses,  $n = 11$ ) and Asiatic black bears (circles,  $n = 13$ ).

**Location**

As predicted, feeding-related cues influenced stereotypy location. Sun bears performed most of their total stereotypy along the cage side from which they were first able to view food arrival (Mann-Whitney tests with “Adjacent-neighbor” ( $W = 129$ ;  $DF = 1$ ;  $P = 0.003$ ); “Adjacent-empty” ( $W = 118$ ;  $DF = 1$ ;  $P < 0.001$ ); and “Wall” ( $W = 182$ ;  $DF = 1$ ;  $P < 0.001$ ); Fig. 5a). This cage side was also frequently

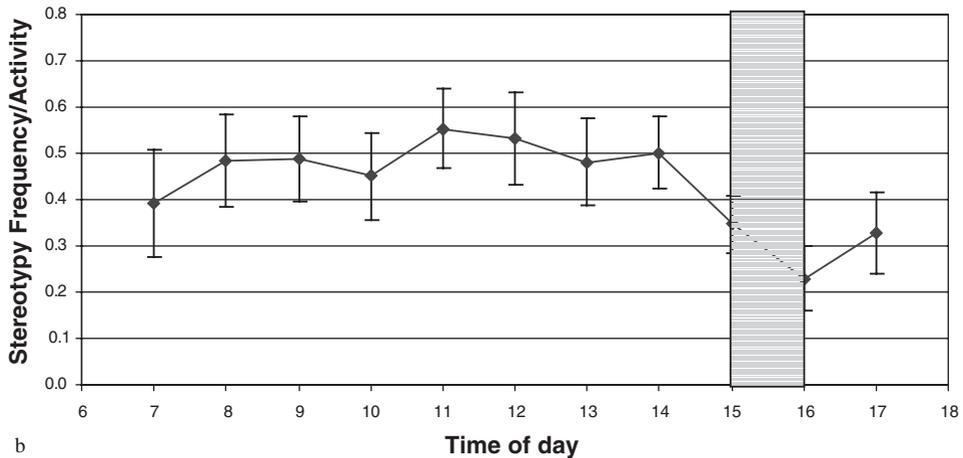
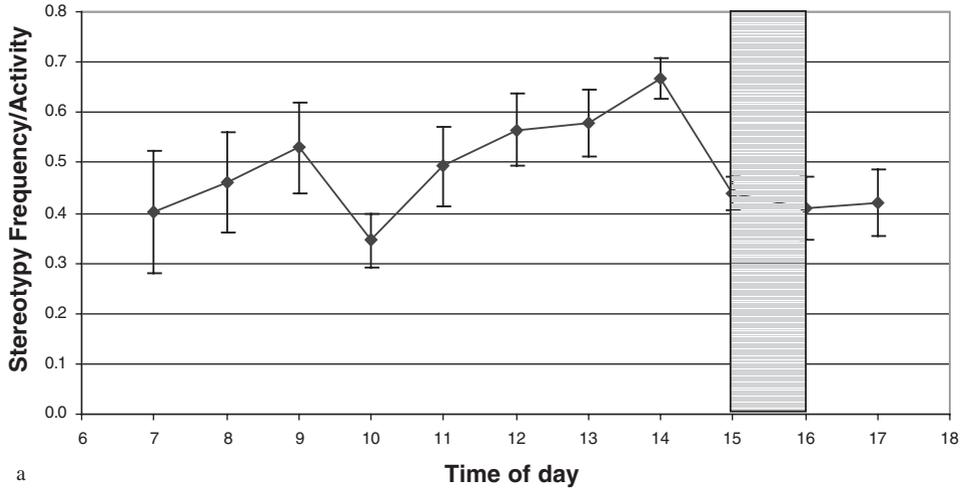


Fig. 4. Temporal distribution of stereotypy (as a proportion of all activities) between 0700 and 1800 hr. Vertical bars represent the SEM, and the shaded area represents observations taken around feeding time (1500–1600 hr). **a:** Malayan sun bears ( $n=11$ ). **b:** Asiatic black bears ( $n=16$ ).

used by Asiatic black bears, although not significantly more so than “Adjacent-neighbor.” Differences only reached significance for “Adjacent-empty” ( $W=63$ ;  $DF=1$ ;  $P=0.045$ ) and “Wall” ( $W=126$ ;  $DF=1$ ;  $P<0.001$ ) (Fig. 5b).

### Other Behaviors

Stereotypy frequency was inversely correlated with inactivity (GLM:  $F_{1,26}=86.4$ ;  $R^2=78.5\%$ ;  $P<0.001$ ), but was unrelated to normal activity levels. Older bears were less active than their younger counterparts, even when their higher levels of stereotypy were statistically controlled for (GLM:  $F_{1,26}=25.67$ ;  $R^2=49.8\%$ ;  $P<0.001$ ), but levels of normal activity did not differ with species or sex. Values of normal behavioral diversity ranged between 0.69 and 2.09

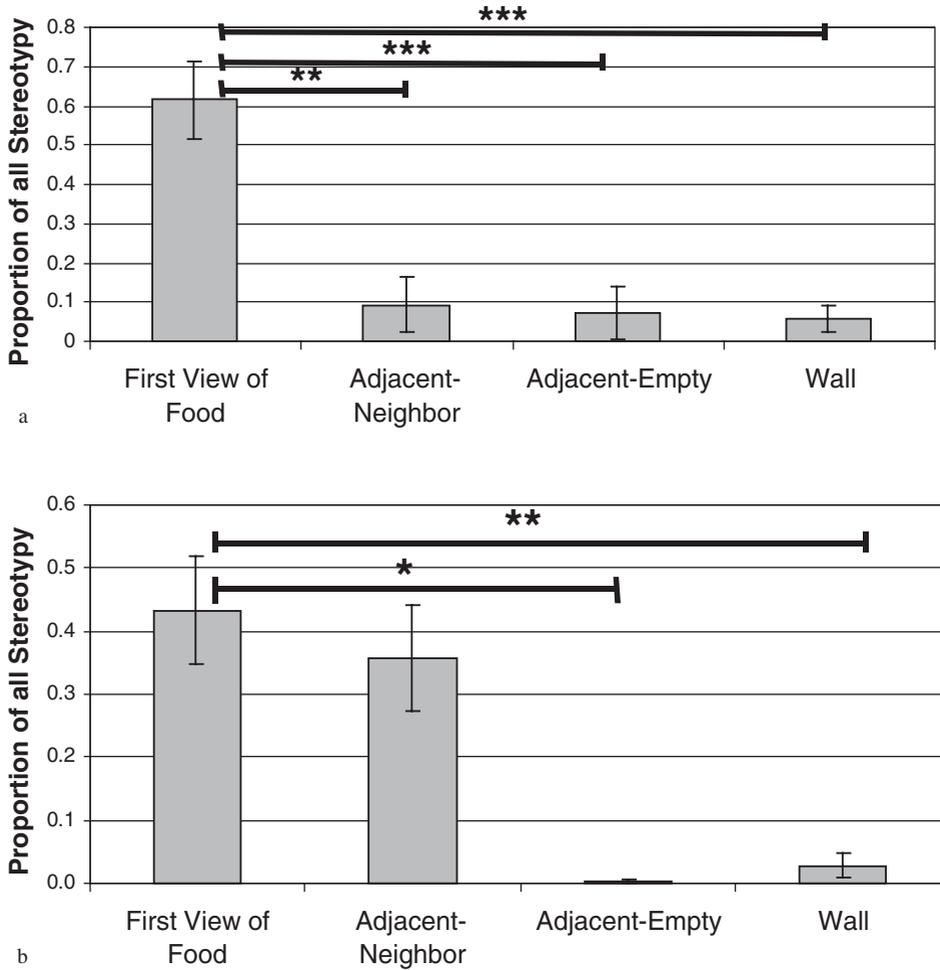


Fig. 5. Mean proportion of total stereotypies performed along cage sides associated with the 1) first view of food arrival, 2) neighboring bear, 3) adjoining empty cage, and 4) cement wall. Vertical bars represent the SEM. **a:** Malayan sun bears (n = 11). **b:** Asiatic black bears (n = 9). \* $P < 0.05$ , \*\* $P < 0.01$ , \*\*\* $P < 0.001$ .

(mean = 1.31; SEM = 0.07 (from a potential maximum value of 3.09)), and were unrelated to stereotypy frequency. Older bears had less diverse behavioral repertoires (GLM:  $F_{1,26} = 24.81$ ;  $R^2 = 48.8\%$ ;  $P < 0.001$ ), but this effect was due to their reduced normal activity levels, and became nonsignificant when normal activity was statistically controlled for.

Compulsive behavior was observed in only 34% of the bears studied. Frequencies of this behavior were low (mean for “performers” = 0.5%; SEM = 0.2) and unrelated to stereotypy frequency, age, or sex, but were significantly higher in sun bears than in Asiatic black bears (Kruskal Wallis:  $H = 5.19$ ;  $DF = 1$ ;  $P = 0.023$ ). Repetitive self-sucking was less prevalent still, being observed in 17% of

bears, although the mean frequencies of this behavior were higher than for compulsive behavior (mean for “performers” = 5.3%; SEM = 4.7). Levels of repetitive self-sucking were unrelated to stereotypy frequency, age, species, or sex. However, the bears that performed this behavior were younger than those that did not (mean age of “performers” = 3.7; SEM = 1.02, and mean age of “non-performers” = 7.7; SEM = 0.4; Mann-Whitney:  $W = 26.0$ ;  $DF = 1$ ;  $P = 0.005$ ).

## DISCUSSION

### General Properties of Stereotypy

Stereotypies were highly prevalent: only two (both female Asiatic black bears) of the 29 bears studied showed no stereotypy at all. Frequencies were highly variable across individuals, occupying up to 51% of daylight hours in the most stereotypic animals. Bears that exhibited higher frequencies of stereotypy performed them more invariantly (although, unexpectedly, variability was not related to age). This finding is consistent with previous observations in farmed mink [Mason, 1993a; Clubb, 2002], and may have implications for treatment, since it appears harder to alleviate less variable stereotypies by enrichment [Vickery, 2003]. As seems typical of bears (see Introduction), and indeed all carnivores [Clubb and Mason, 2001], locomotory stereotypies, such as pacing, predominated. The number of different forms or sequences performed was unrelated to stereotypy frequency. Interestingly, oral stereotypies, but not locomotory or “other” forms, increased in frequency after the bears were fed. Similar post-feed oral stereotypies have been well-documented in other taxa (e.g., pigeons [Palya and Zacny, 1980], pigs [Rushen, 1984], and poultry [Kostal et al., 1992]), and have often been attributed to an inability to carry out feeding or specific foraging behaviors (for review see Mason and Mendl [1997]).

Stereotypies were primarily concentrated in the hours of daylight and peaked prior to the bears' scheduled feeding time, a finding previously reported for other bear species [e.g., Wechsler, 1991; Langenhorst, 1998; Landrigan et al., 2001] and other carnivores [e.g., Mason, 1993a; Carlstead, 1998; Clubb, 2002]. A less substantial stereotypy peak was also observed in the early morning, perhaps reflecting an increased motivation to feed or locomote at this time of day. In the wild, many diurnal species begin the day with an intense period of feeding or other activity [Oates, 1986], and peaks in locomotion shortly after sunrise have been observed in wild bears [Garshelis and Pelton, 1980; Nawaz, 2002]. Alternatively, this peak may reflect the first human disturbance of the day, since the keepers arrived at ~0800 hr.

Along with the timing of stereotypies, the main location in which they occurred (i.e., along cage sides from which food arrival could be viewed) suggested that feeding motivation played an important role. Similarly, captive felids have been observed to pace in areas from which they could see their keeper approach [Carlstead, 1998], and mink have been reported to orientate their stereotypies toward an approaching food cart [Mason, 1993a]. Interestingly, however, the Asiatic black bears (but not the sun bears) were equally likely to exhibit stereotypy along a cage side adjoining a neighbor's cage. This behavior may have represented (or developed from) territorial patrolling or attempts to prompt interaction with the neighboring animal, or this cage side may have been favored simply because it offered greater sensory stimulation. As expected, the concrete wall and the cage side adjoining an

empty cage were the least-used areas for stereotypy. Overall, the order of use of the different cage sides highlights the importance of feeding, and suggests that (as has been reported for other species [e.g., Nevison et al., 1999; Roynon, 2000, cited in Knowles and Plowman, 2001]) bears perform stereotypies in locations that offer high levels of sensory stimulation. Unfortunately, however, we were unable to determine whether these areas were particularly preferred for stereotypy, or were favored for all activities, with the data collected.

### **Relationships Between Stereotypy and Other Behaviors**

Stereotypy frequencies were inversely correlated with levels of inactivity, but were unrelated to normal activity levels, contrary to previous findings in polar bears [Ames, 2000]. Thus, the stereotypic bears were less inactive but showed the same amount of normal behavior as the less stereotypic animals. In contrast to some studies of other animals [Stolba et al., 1983; Dantzer, 1986; Gunn and Morton, 1995], higher levels of stereotypy were not associated with a reduced diversity of normal behavior, even though other studies of these subjects have shown a link between stereotypy and general behavioral persistence [Vickery and Mason, 2003] (Vickery and Mason, in press). Finally, a bear's stereotypy frequency also did not predict its level of compulsive or repetitive self-sucking behavior, which suggests that different motivations and/or processes may underlie these different abnormal behaviors [Garner, 1999].

### **Age-Related Changes in Stereotypy and Other Behaviors**

Stereotypy frequency increased with age, consistent with previous findings in other taxa [e.g., Cronin and Wiepkema, 1984; Mason, 1993a; Würbel et al., 1996]; however, unexpectedly, invariance did not increase with age. Some evidence of emancipation was also found, in that bears with higher total frequencies of stereotypy performed a greater proportion of their total stereotypy outside the pre-feed period. (This was not true of older bears or those with more invariant stereotypies, however.) High stereotypers were also more likely to exhibit stereotypy at night, and there was a related trend for age to predict nocturnal stereotypy. However, it should be noted that this line of reasoning assumes that the bears' stereotypies first arose in the pre-feed period and then became emancipated in other contexts. This seems plausible given that all bears performed stereotypies in the time before food delivery, but it remains to be confirmed by longitudinal studies. An alternative explanation is that older bears simply acquire more diverse motivations for stereotypic behaviors.

The number of different stereotypic forms or sequences was unrelated to a bear's age, which suggests that stereotypies became neither more elaborate [c.f., Goosen, 1981; Cronin and Wiepkema, 1984] nor more restricted (as suggested by some hypotheses of stereotypy development [e.g., Fentress, 1976, 1977]) through repetition.

Older bears exhibited lower levels of normal activity, as previously reported for polar bears [Ames, 1994, 2000], and also showed an associated reduction in behavioral diversity. Importantly, reduced normal activity with age was not simply due to behavioral competition with increasing levels of stereotypy. This effect persisted even when stereotypy frequency was statistically controlled for. Normal activity may decline as a consequence of time spent in captivity, or, alternatively, the

decline may represent the natural progression of behavior, given that wild adults are often less active than their subadult counterparts [Garshelis and Pelton, 1980; Reid et al., 1991] (although it is not clear whether activity levels in the wild lie along the continuum found here or fall into more distinct age brackets).

Although levels of compulsive behavior and repetitive self-sucking did not covary with age, as a group the bears that engaged in self-sucking behavior were significantly younger than those that did not. In other species, some deprivation stereotypies have been reported to occur most frequently in young animals and then decline with age [e.g., Cross and Harlow, 1965]. This may be further evidence that this well-reported but often ambiguously interpreted behavior (e.g., it can be viewed as a sign of contentment or a displacement activity [Domico, 1988]) is indeed a deprivation stereotypy stemming from premature weaning.

### Species Differences

Overall, stereotypy frequencies did not differ between the two species, but in the period prior to feeding, the sun bears performed significantly more stereotypies than the Asiatic black bears. The sun bears also performed significantly more of their total stereotypic behaviors along cage sides from which they could view food arrival, exhibited a greater diversity of stereotypy forms and sequences, and displayed a higher frequency and greater number of oral stereotypies (a form often associated with thwarted feeding motivation [Samraus, 1985; Kostal et al., 1992; Bashaw et al., 2001]). They also showed more compulsive behavior (e.g., hair-plucking).

Prior to this study, the Asiatic black bears had occasional access to an outdoor grass enclosure, whereas no such enclosure existed for the sun bears. Other than that, however, the rearing, husbandry, and housing conditions were virtually identical, and the two species did not differ in age. It therefore seems likely that differences in their stereotypies reflect biological species differences. Interestingly, the main differences were feeding-related, perhaps reflecting differences in the natural feeding ecology of the two species. Although both species are naturally omnivorous and spend large proportions of their time foraging, the sun bear's distribution is closer to the equator than the Asiatic black bear's, hence their food sources probably fluctuate less with the seasons. In contrast to Asiatic black bears, which rely on seasonally available fruits and vegetation [Schaller et al., 1989; Reid et al., 1991], sun bears typically consume large quantities of invertebrates, such as termites and beetle larvae, which are available year round [Wong et al., 2002]. Compared to sun bears, Asiatic black bears also appear to maintain larger annual home ranges and travel greater distances each day: home range sizes for adult males have been reported to be 36–50 km<sup>2</sup> (based on eight individuals [Reid et al., 1991; Hazumi, 1994]) and 6–20 km<sup>2</sup> (based on four individuals [Wong, 2002]) respectively, while daily distances traveled have been reported in the region of 3–6.8 km per day for Asiatic black bears [Reid et al., 1991] and 1.45 km per day for sun bears [Wong, 2002]. These figures suggest that the Asiatic black bear's food sources may be more widely dispersed. (Interestingly, although wide-ranging carnivores have been reported to be more prone to stereotypy [Clubb and Mason, 2003], this was not true of these two species, since their overall stereotypy frequencies did not differ. This may indicate that other biological factors are important too, or may merely reflect their slightly different previous housing conditions.)

Differences in natural foraging behavior and activity may therefore underlie the species differences in stereotypy outlined above. Perhaps because their feeding habits are less seasonally variable, sun bears are more prone to developing oral stereotypies when their foraging behaviors are not allowed for in captivity, whereas the naturally more flexible feeding behavior of Asiatic black bears may be less affected. Alternatively, the observed differences may stem from differences in the time the two species spend foraging in the wild, their temporal patterns of foraging activity, or the type of foraging behaviors they employ, because these may dictate how they adapt to feeding in captivity. These hypotheses are speculative at this stage, since the natural feeding ecology of the two species (particularly the sun bear) is still poorly understood. However, natural ecology undoubtedly plays an important role in the development of stereotypies [e.g., Mason and Mendl, 1997; Clubb and Mason, 2003], and hence might well explain this interesting species difference.

### **Relevance of Findings to Other Zoological Facilities**

Although the housing and husbandry conditions of these bears differed widely from those of many zoological facilities (e.g., good Western zoos), the main findings of this study are still relevant to the management of captive bears in general. The stereotypy frequencies were well within the ranges reported for bears housed in European and North American zoological facilities [e.g., Forthman et al., 1992; Spendrup and Larsson, 1998; Ames, 2000]. Also, other properties of the bears' stereotypies (i.e., form, variability, timing, and location), and the developmental changes observed, are in accordance with reports of stereotypy in bears and other animals studied in quite different setups. Clearly, the precise influences on stereotypy for the bears studied here may well differ from those observed in bears held in more conventional zoo facilities (for example, the provision of just one meal per day may have led to an inflated effect of feeding on their stereotypies). However, the findings of this study offer general, statistically tested, and important insights into probable motivations, patterns, and relationships that would be very difficult to ascertain in bears housed in zoos.

### **How Might Examining the Properties of Stereotypies Improve our Ability to Tackle Them?**

The basic properties of stereotypies (how, when, and where they are performed) are not arbitrary, but relate to how and why the behavior developed. Form, timing, and location can sometimes indicate the motivations that underlie a stereotypy, while frequency, variability, and the degree to which a stereotypy is emancipated might reveal its stage of development (discussed further in Vickery and Mason [2003b]).

It is important to understand the underlying causes of a stereotypy in order to treat it, and to reduce such behaviors in the long term [e.g., Carlstead and Seidensticker, 1991; Kolter and Zander, 1995]. In the current study, stereotypies were primarily locomotory in form, suggesting that thwarted locomotion (perhaps to seek food or mates, patrol a territory, or escape) may underlie these behaviors. Also, as discussed above, the higher incidence of oral stereotypy exhibited by the sun bears further suggests that thwarted feeding or foraging motivations may play a significant role in their stereotypy, and more so than in the Asiatic black bears. Both the timing of the bears' stereotypy (concentrated in the period prior to feeding) and (especially

in sun bears) the location in which it was performed (along cage sides from which food arrival could be viewed) further indicate the importance of the feeding event (particularly for sun bears) and point to a role of thwarted feeding and/or foraging. Thwarted feeding-related motivations may underlie stereotypy directly or indirectly—for example, by increasing the aversiveness of an environment that offers little opportunity for feeding/foraging, hence increasing the motivation to escape, or by increasing arousal when food is not forthcoming. Husbandry changes, such as increasing the frequency of feedings, offering a more natural diet (in terms of food types and diversity), and providing food earlier in the day, might reduce these motivations and hence alleviate stereotypy.

However, some caution is needed when one interprets the timing of a stereotypy. As we have seen here, more established stereotypies may be performed in more diverse situations that may not necessarily correspond to the original cause. Furthermore, stereotypies may peak in the pre-feed period simply because of anticipation of an important event (c.f., schedule-induced behavior [Staddon, 1977; Mistlberger, 1994]), with the regular scheduling of food either inducing stereotypy in the pre-feed period due to high arousal at that time, or influencing the timing of stereotypy that develops from other causes, so that it becomes concentrated prior to food arrival. Indeed, regularly scheduling other nonfood events (such as access to drinking water or to a conspecific) during a captive animal's day can similarly trigger anticipatory peaks in activity [Mistlberger, 1992; Van den Berg et al., 1999], and perhaps in stereotypy as well.

The other properties of stereotypy assessed here—frequency and “Invariance”—were shown to increase with age, which suggests that they may reflect the degree of establishment of the behavior. Established stereotypies (as assessed by age, stereotypy frequency, and invariance) typically are more difficult to alleviate by environmental enrichment [Sorensen, 1987, cited in Powell et al., 2000; Cooper et al., 1996; Vickery, 2003], and therefore these measures might be useful for identifying those individuals that are likely to respond best to enrichment attempts. Also, since well-developed stereotypies might have become emancipated from their original underlying motivations, these measures of development may also predict how faithfully the properties of a stereotypy reveal its original cause.

## CONCLUSIONS

1. The stereotypies of Asiatic black and Malayan sun bears were primarily locomotory in form, concentrated in the hours of daylight, peaked immediately prior to feeding, and performed in locations from which food arrival could be viewed (both species) and alongside a neighbor (Asiatic black bears only).

2. High frequencies of stereotypy were associated with less variable movements and reduced inactivity (resting/sleeping), but not with a reduced level or repertoire of normal behavior.

3. Older bears displayed higher frequencies of stereotypy and lower levels of normal activity, which were associated with a reduced behavioral repertoire. It is unknown whether this reflects age per se or a greater number of years spent in captivity. However, unexpectedly, their stereotypies were not less variable.

4. Some evidence of emancipation (i.e., the performance of stereotypy in more diverse situations) was found, in that bears with higher overall frequencies of

stereotypy were more likely to perform stereotypies at night as well as in the day, and also performed a greater proportion of their total stereotypy outside the pre-feed period.

5. Levels of total stereotypy did not differ between the species; however, compared to the Asiatic black bears, the sun bears performed a greater proportion of their stereotypy in areas from which they could view food arrival, exhibited significantly higher pre-feed stereotypy peaks, and showed a greater number of stereotypy forms and sequences, a higher frequency of oral stereotypies, and more compulsive behavior.

6. In general, most efforts to alleviate stereotypy would benefit from such detailed analyses, since the properties of stereotypies may offer clues to their motivational bases and degrees of establishment.

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