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BRIEF REPORT

Time-Budgets and Activity Patterns of Captive Sunda Pangolins (*Manis javanica*)

Daniel W. S. Challender,[1]* Nguyen Van Thai,[2] Martin Jones,[3] and Les May[3]

[1]Durrell Institute of Conservation and Ecology (DICE), School of Anthropology and Conservation, University of Kent, Canterbury, Kent, United Kingdom
[2]Carnivore and Pangolin Conservation Programme, Cuc Phuong National Park, GPO, Ha Noi, Vietnam
[3]Division of Biology, School of Biology, Chemistry and Health Science, The Manchester Metropolitan University, John Dalton Building, Chester Street, Manchester, United Kingdom

This is the first assessment of *Manis javanica* behavior in captivity. The aim of the investigation was to assess behavior in order to suggest ways of improving captive care and management of the species. This was undertaken by constructing time-budgets and activity patterns and identifying any abnormal repetitive behavior (ARB) exhibited. Scan and focal animal sampling were implemented in observations of seven subjects. Analyses detailed idiosyncrasies in how subjects partitioned their active time. Peak activity occurred between 18:00 and 21:00 hr. Two ARBs, clawing and pacing, were identified and the cessation of clawing in one subject was possible by modifying its enclosure. Stress-related behavior, understood to be related to several factors, means maintaining this species in captivity remains problematic. Recommendations are made pertaining to husbandry, captive management, and future research. Zoo Biol 29:1–13, 2011. © 2011 Wiley-Liss, Inc.

Keywords: Pholidota; captivity; behavior; activity; husbandry

*Correspondence to: Daniel W. S. Challender, Durrell Institute of Conservation and Ecology (DICE), School of Anthropology and Conservation, University of Kent, Canterbury, Kent, UK.
E-mail: dan_pangolin@hotmail.co.uk

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INTRODUCTION

Pangolins (*Pholidota:Manidae*) are insectivorous mammals inhabiting tropical and subtropical forests, thick bush and open savannah regions in Africa and Asia [Nowak, 1991]. Anatomically adapted to a specialist diet of ants and termites [CITES, 2000; Lekagul and McNeely, 1988; Nowak, 1991; Swart et al., 1999] they are understood to be solitary and nocturnal [Heath, 1987; Heath and Vanderlip, 1988; Macdonald, 2006; Nowak, 1991].

The arboreal Sunda pangolin *Manis javanica* is distributed across the forests of Southeast Asia and Indonesia [Francis, 2008; Gaubert and Antunes, 2005; Payne et al., 1985]. It is listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora [CITES, 2009] and is classified as endangered [A2d+3d+4d; Duckworth et al., 2008]. Hunting to supply the international wildlife trade and habitat loss are major threats facing the species [CITES, 2000].

Pangolins are infrequently exhibited in zoos [Wilson, 1994; Yang et al., 2007] and there has been limited success in maintaining arboreal species of pangolin in captivity [Heath and Vanderlip, 1988]. There are 19 Sunda pangolins maintained in three zoos and rescue centres worldwide. Research on captive pangolins has been limited but has focused on dietary husbandry [see Yang et al., 2007], the Chinese pangolin *Manis pentadactyla* [see Chen et al., 2005; Heath, 1987; Heath and Vanderlip, 1988], and pangolin husbandry more broadly [see Hoyt, 1987; Wilson, 1994]. Much of what is known about *M. javanica* is anecdotal [Lim and Ng, 2007].

Asian pangolins are hunted and illegally traded in huge quantities attributed to demand from China and other markets for food and Traditional Chinese Medicine. In parts of Southeast Asia pangolins seized from the trade are maintained in rescue centres and are known to develop gastric stomach ulcers. Given the absence of evidence of an infectious etiology, it is believed that stress, induced by both the trade and the captive setting, plays a significant role in the development of these often fatal ulcers [Clark, personal communication]. Causes of stress in captivity are unknown but suspected factors are a sub-optimal diet, proximity to conspecifics in males, enclosure size, and nervousness around people [Clark, personal communication].

Stereotypic behavior, in the form of pacing, has been observed in captive Chinese pangolins [Schwindy, personal communication] and observations of abnormal behavior in the subjects before this study present the reasons for investigating abnormal behavior. To investigate abnormal behavior, we adopted the term “abnormal repetitive behavior” (ARB) suggested by Garner [2008]. It conveys nothing about causation and it is suggested as appropriate for use where the cause of repetitive behavior, defined as invariant behaviors performed repetitively with an apparent lack of function, is unknown [Mason, 1991; Mason et al., 2007; Ödberg, 1987].

The aim of this investigation was to assess behavior in order to suggest ways of improving captive care and management. The objectives were to: (1) determine time-budgets and activity patterns and (2) determine whether individuals displayed ARB.

METHODS

Location and Subjects

The study was undertaken over 34 nights between March 23 and April 26, 2008 at the Carnivore and Pangolin Conservation Programme facility, Vietnam. The geographic range of *M. javanica* in Vietnam is restricted to central and southern

TABLE 1. ID, Sex, Life Stage, Rearing Condition, Acquisition Date, Source, Weight, Enclosure, and Number of Focal Animal Samples (FAS) Collected for Each of the Study Subjects

ID#	Sex	Life stage	Rearing condition	Acquisition date	Source	Weight (kg)[a]	Enclosure	No. of FAS
P3	♀	Adult	Mother	9 October 2006	Confiscated	3.65	T1	34
P5	♀	Adult	Mother	11 December 2006	Confiscated	3.4	T4	36
P7	♀	Adult	Hand	11 December 2006	Confiscated	3.85	T4	47
P8	♂	Adult	Mother	11 December 2006	Confiscated	5.05	T3	39
P11	♀	Adult	Mother	Unknown	Confiscated	3.9	T2	24
P19	♂	Juvenile	Mother	–	22 November 2007[b]	0.7	T2	19
P21	♀	Adult	Mother	25 December 2007	Confiscated	2.05	Q2	53

[a]Weights recorded: P5 (27 January 2008), P19 (17 February 2008), P21 (17 March 2008), P3, P7, P8, P11 (21 March 2008).
[b]D.O.B., Lineage: P11 × Wild male.

provinces [Newton et al., 2008]; consequently, the study was conducted on subjects maintained outside their natural range. Seven animals were observed and comprised an adult male, five adult females, and a juvenile male (Table 1). All subjects were confiscated from the wildlife trade in Vietnam and were wild born with the exception of the juvenile male.

Housing and Husbandry

Subjects P3, P8, and P21 were housed individually, whereas P11 and P19 (mother and offspring) were housed together (Table 1). P5 and P7 were housed together throughout the study as they had been housed together from a young age (weighing 1.3 kg and 700 g respectively, when introduced); P7 was hand-reared. With the exception of P21, subjects were housed in enclosures in the "Pangolarium," each measuring 29 m^2. Enclosures measured 4.1 m in height which included a soil depth of 1.0 m. The enclosures consisted of concrete walls and 2″ chain link fencing which was also used as enclosure ceilings. P21 was housed in an enclosure similar in design to the other enclosures but had an area of 5.2 m^2. This enclosure stood approximately 15 m from the pangolarium and had a concrete floor.

Before the study, bamboo matting had been added to fencing in the pangolarium to act as a visual barrier between adjacent enclosures. This was an effort to reduce stress-related behavior, believed to be caused by close proximity to conspecifics [Clark, personal communication]. Part way through the study the bamboo matting was removed from the enclosure of P3, in response to clawing behavior directed toward it, and the effect of this on the subjects' behavior was noted for discussion.

All enclosures contained furniture consisting of a complex network of Lychee branches (*Litchi chinensis*) of varying diameters. The network of branches extended to at least three sides of each enclosure and from the floor to just short of the ceiling fencing. Concrete burrows were buried in the soil and drainage pipes acted as burrow entrances. Each burrow was lined with a wooden bed box (approximately 1 m in length × 0.5 m × 0.5 m) that contained dried leaf litter as a bedding material. Bed boxes were approximately 1 m beneath the surface of the soil and were accessible to keepers via a sunken keeper corridor. Subjects were known to defecate in water bowls, therefore two were provided (~60 cm in diameter, ~15 cm deep, ~1/2 full). One was offered as an alternative to litter trays [Heath and Vanderlip, 1988] and the second to provide access to water as these animals are known to swim in the wild.

Subjects were offered fresh food items daily between 17:30 and 18:00 hr which took one keeper ~15 mins and included spot cleaning the enclosures. Live and frozen weaver ants (*Oecophylla smaragdina*) were offered in two ways. Live ants were offered in metal feeding bowls that contained a moat to stop them escaping. Second, *Oecophylla smaragdina* were frozen before feeding and offered in porcelain bowls to ensure that sufficient food was provided. Nests of *Crematogaster* sp. of ant were harvested from local forests daily and each subject offered one nest.

Data Collection and Statistical Procedures

Time-budgets

Data collection was undertaken by DC and NVT during the period 17:00–05:00 hr each night. Nocturnal observations were possible by illuminating the enclosures with red light, a method that has been used previously to observe nocturnal mammals [e.g. Elangovan and Marimuthu, 2001; Finley, 1959].

The study focused on 14 behavioral states, which were subcategories of five super category behaviors [Forthman and Bakeman, 1992]. Each behavioral state was defined in operational terms [Martin and Bateson, 2007] and formed the ethogram used (Table 2). Behaviors were both exhaustive and mutually exclusive [Bakeman and Gottman, 1997]. Time-budgets focused on how subjects partitioned their active time. Behaviors observed that were not in the ethogram were recorded as *other* and noted for discussion. Two such behaviors identified this way were *resting* and *pacing* which have been defined, see Table 2.

The continuous recording method was implemented using an Olympus Digital Voice Recorder providing an exact record of the time at which behavioral states began and ended [Martin and Bateson, 2007]. Scan samples undertaken determined if subjects were active during a walk past each enclosure in a predetermined order [Altmann, 1974]. The first subject sighted as active was the focus of a 15-min focal animal sample [Altmann, 1974]. Subsequent scans commenced at the next quarter hour if no subject was active or the next half hour if a subject was sighted as active and observed, subject to observer rules. This methodology was followed to allow as much data as possible to be collected from all subjects. The proportions of time spent in behavioral states were extracted from audio files using RecorderV software [RecorderV, courtesy of Dr. Les May, Manchester Metropolitan University]. Time spent *out of sight* was omitted from analyzed samples to avoid analysis where the majority of behavior was unknown, but was noted for discussion. MANOVA was conducted to test for significant differences between how the subjects partitioned time between super category behaviors. Before MANOVA, log ratio analysis allowed data to be freed from the constraint that percentages necessarily sum to 100%. The analysis was undertaken in PAST (PAleontological STatistics ver. 1.81, Norway).

Abnormal repetitive behavior

Observations of behavior that fitted the definition of ARB throughout focal animal samples were noted for discussion.

TABLE 2. Ethogram of *Manis javanica* Behaviors Used in the Study

Super category	Key	Behavioral states, operational definitions
Feeding	**(F)**	Frozen ants—Individual has head lowered below level of back and sticks out tongue to consume frozen *O. smaragdina*, often interspersed with brief pauses (less than 3 sec).
	(L)	Live ants—Individual intersperses brief use of forelimbs to move leaf matter and sticks out tongue to consume live *O. smaragdina*, individual maybe in the feeding bowl, often interspersed with brief pauses (less than 3 sec).
	(E)	Black ants—Individual intersperses brief use of forelimbs to break into ant nest and sticks out tongue to consume *Crematogaster* sp.
	(Y)	Drinking—Individual has head lowered below the level of back and sticks out tongue to consume water.
Locomotion	**(W)**	Walking—Quadrupedal locomotion often with nose/head outstretched in more than one direction interspersed with very brief pauses (less than 3 sec) and/or brief use of forelimbs (less than 3 sec) to touch/move substrate.
	(C)	Climbing—Individual uses two or more limbs and/or tail to climb on the enclosure fencing, door, enclosure furniture (e.g. logs and branches) or walls of the enclosure, locomotion is often interspersed with brief pauses (less than 3 sec).
	(G)*	Pacing—Quadrupedal locomotion, following the same or similar route in repetition, often with nose/head outstretched in more than one direction interspersed with very brief pauses (less than 3 sec).
Social	**(M)**	Social (Mount)—Individual uses some or all of limbs in an attempt to mount conspecific or is mounted on the back and/or tail of conspecific.
	(S)	Social (Other)—Individual engages in any form of physical contact with conspecific apart from mounting, e.g. individual uses some or all of limbs to wrestle/roll around with conspecific.
Hidden	**(O)**	Out-of-sight—Individual cannot be seen and its behavior is unknown.
	(B)	Bed box—Individual is in the bed box or tunnel to the bed box and its behavior is unknown.
Other	**(D)**	Digging—Individual uses forelimbs to dig/break up the ground/dig within logs/tree trunks, usually churning up soil and/or fragments of logs.
	(P)	Paused—Individual is still and inanimate for 3 sec or more, either on all four limbs or raised on hind limbs with forelimbs in the air, usually raising its nose/head to the air in more than one direction.
	(X)	Clawing—Individual uses some or all of limbs and/or tail to climb on the enclosure fencing/door, rapidly putting head and forelimbs backwards and forwards through the fencing while rapidly clawing at the fencing/door to the enclosure.
	(T)	Other—Individual displays any other type of behavior not included in this ethogram, e.g. time taken to defecate, clean or spend in water.
	(R)*	Resting—Individual is inanimate, its ventral body surface is close to the ground with or without its limbs at full stretch.

*Behaviors not included in the ethogram used in the study, but identified and defined throughout the study.

Activity patterns

Scan samples determined if subjects were active at intervals of 15 or 30 min for the duration of each night. Activity patterns were constructed by calculating the proportion of circuits on which subjects were active. Analyses of activity throughout the night were undertaken by dividing a night into logical periods of time (e.g. 17:00–17:45 hr).

Observer reliability

Cohen's Kappa coefficient was used to assess inter-observer reliability, allowing for chance agreements between observers [Bakeman and Gottman, 1997; Martin and Bateson, 2007]. Observer–agreement assessments were undertaken three times throughout the study.

RESULTS

Time-Budgets

The number of focal animal samples obtained for subjects ranged from 19 to 53 ($n = 7$), see Table 1. There was a significant overall difference in the amount of time spent in super category behaviors between subjects (MANOVA, Pillai trace $F = 4.789$, *d.f.* 18, *d.f.*2. 735, $P < 0.001$). Post hoc analysis, using Hotelling's pairwise comparisons, revealed that there were both significant and nonsignificant differences between subjects when compared individually (Table 3). There were no significant differences between P11 and P3 or P21 despite P11 being housed with offspring (Fig. 1). Similarly, as with P11, there was not a significant difference between P3 and P21 despite being housed in different types of enclosures. Where adult conspecifics were housed together, P5 and P7, there was no significant difference between the two subjects but the opposite was true for P11 and P19. Significant differences in the time spent in super category behaviors were also apparent for both P3 and P21 when compared with P5 and P7 (Table 3). Time allocated to all behaviors toward the procurement of food and water (F, L, E, and Y, supercategory "Feeding") ranged from $21.8 \pm 2.8\%$ (mean $\pm$ standard error) in P7 to $43.5 \pm 6.5\%$ in P11. Time spent in the supercategory "Locomotion" (W and C) ranged from $13.4 \pm 3.5\%$ in P19 to $40.7 \pm 3.9\%$ in P21.

TABLE 3. MANOVA Results, *P*-values are Hotelling's Pairwise Comparisons, Bonferroni Uncorrected Values

Subject	P3	P5	P7	P8	P11	P19	P21
P3	–	***<0.001***	***<0.001***	***<0.001***	0.637	***<0.001***	0.109
P5	–	–	0.662	***0.012***	0.055	0.110	***0.036***
P7	–	–	–	0.143	***0.001***	***0.031***	***<0.001***
P8	–	–	–	–	***<0.001***	***0.011***	***<0.001***
P11	–	–	–	–	–	***0.007***	0.307
P19	–	–	–	–	–	–	***<0.001***
P21	–	–	–	–	–	–	–

Significant differences between subjects are italicized.

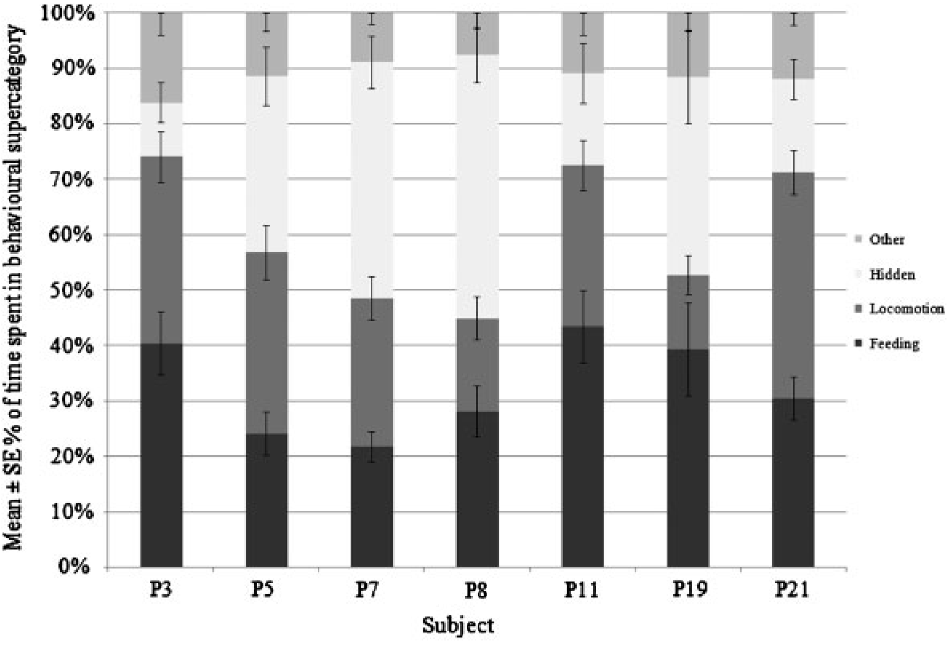

Fig. 1. Descriptive time-budgets, mean ± SE % of time spent in behavioral super categories.

The proportion of time spent in behavioral states varied between subjects (Fig. 2A–G). Notably P11 and P19 spent greater proportions of time *out of sight* than other subjects, 17.3 ± 4.5% and 11.4 ± 3.6%, respectively. P3 spent 7.2 ± 2.2% *out of sight*. The highest proportion of time spent feeding on any one food item (F, L or E) was P11 which spent 28.1 ± 5.5% of its active time feeding on frozen ants (Fig. 2E). P19 spent a comparable proportion of time feeding on black ants. P19 also spent the least proportion of time walking (4.94 ± 1.09%), in contrast to P11 which spent the greatest, 21.8 ± 3.3%. *Digging* was observed in all individuals, except P21, though it comprised only a small proportion of active time-budgets; between 0.1 ± 0.1 (P7) and 4.1 ± 2.2% (P3). In contrast, P21 spent the greatest proportion of time climbing of all subjects, 32.3 ± 4.0%. *Mount* behavior was exhibited predominantly by P19, an animal which spent 6.4 ± 2.5% of its active time in this state (Fig. 2F). Notable time spent in *social* behavior was exhibited by P11 (3.9 ± 3.9%). Time spent in behaviors not included in our ethogram included *resting*; P5, P7 and P8 each spent <6 % of their active time in this state but incidences of this behavior only occurred in the latter stages of the study.

Abnormal Repetitive Behavior

Behavior believed to be related to stress and identified as an ARB, *clawing*, comprised a small percentage of the active time-budgets of three subjects, P3, P8 and P21 (3.9 ± 2.1, 0.07 ± 0.07, and 3.4 ± 1.6%, respectively; Fig. 2A, D, and G). *Pacing* behavior, not included in our ethogram but identified as an ARB, was observed predominantly in P5 but also in P7 and P8 and involved the subjects pacing a route around their enclosures.

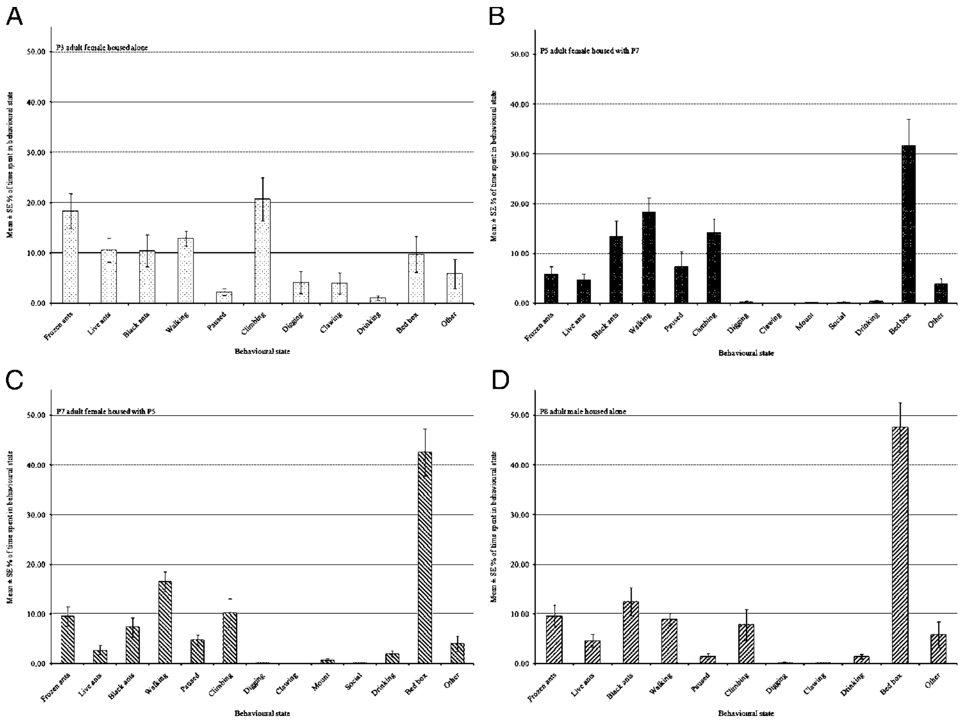

Fig. 2. (**A**) P3 descriptive time-budget; (**B**) P5 descriptive time-budget; (**C**) P7 descriptive time-budget; (**D**) P8 descriptive time-budget; (**E**) P11 descriptive time-budget; (**F**) P19 descriptive time-budget; and (**G**) P21 descriptive time-budget.

Activity Patterns

Subjects were active intermittently over a period of 12 hr in the period 17:00–05:00 hr (Fig. 3). P8 and P21 were sighted as active on circuits between 17:00 and 17:45 hr and on one occasion P8 was sighted as active until shortly after 05:00 hr. Where subjects were housed with a conspecific, both subjects were sighted as active most frequently within the same time period (Fig. 3). Despite inconsistent activity patterns, a peak activity period between 18:00 and 21:00 hr is suggested.

Observer Reliability

Observer–agreement assessments resulted in scores of 0.94, 0.90, and 0.92, which were considered excellent [Fleiss, 1981].

DISCUSSION

The MANOVA analysis detailed significant and nonsignificant differences between how subjects partitioned active time between super category behaviors which suggests idiosyncrasies in the behavior of the subjects. It was perhaps surprising that there were not significant differences between P11 when compared with other adult females, P3 and P21, as P11 was thought to be exhibiting some level of maternal care, so a difference may have been expected. A significant difference may also have been expected between P21 and P3 and P11 as a result of differences

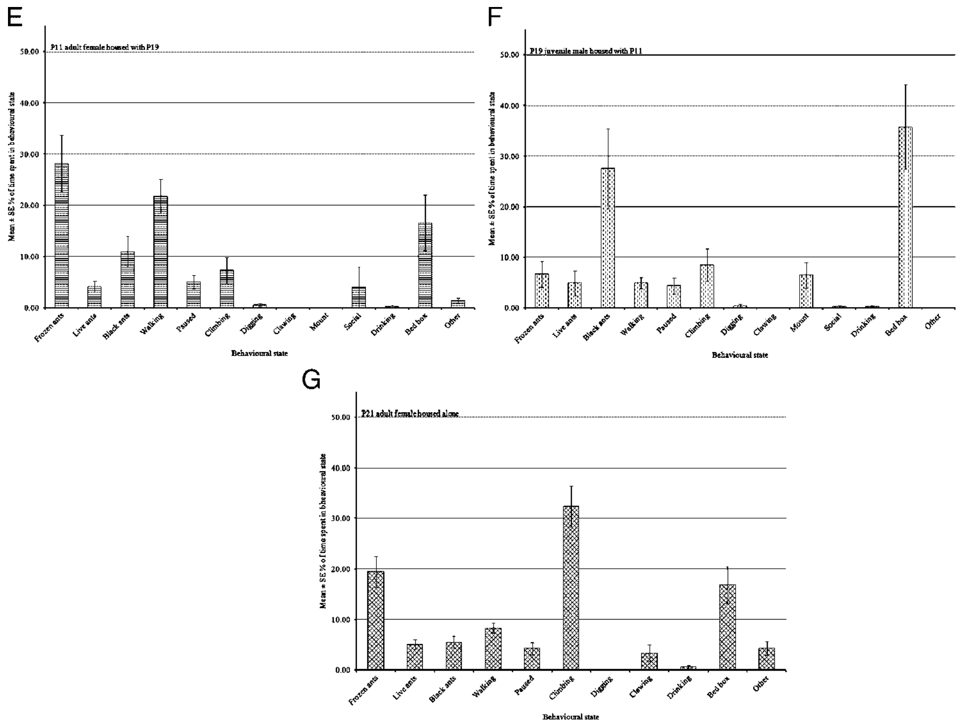

Fig. 2. *Continued.*

between enclosures in the Pangolarium and that of P21, e.g. the lack of a soil substrate. The highest proportion of time spent *climbing* by P21 perhaps suggests that more active time was spent in this behavior because of the lack of an opportunity to dig. The lack of a significant difference between how P5 and P7 partitioned their active time was conceivable; as the two animals had been raised together the behavior of one subject potentially affected the behavior of the other. The significant difference between P11 and P19, an adult female and its 4-month-old offspring was perhaps expected for reasons discussed in this paper.

Significant differences in how the subjects partitioned their active time when housed individually and when housed with an adult conspecific of the same sex, e.g. between P3 and P5 and P3 and P7 suggest individual active time-budgets are affected by the presence of a conspecific. This is supported by the fact that significant differences were also apparent between P21 and P5 and P21 and P7. However, this was not the case for P8, the only adult male in the study. Although the limitations of the small sample size in this study are acknowledged, the behavior of subjects in relation to conspecifics is an opportunity for future research.

The greater amount of time spent in the super category "Feeding" by P11 could be attributed to returning to condition post parturition (4 months previously). No significant difference in the time allocated to super category behaviors between P11 and other adult females housed individually supports this assumption. The greatest amount of time spent in "Locomotion" by P21 is likely due to the absence of a substrate for *digging*; time being spent both in *walking* and *climbing* instead, as discussed.

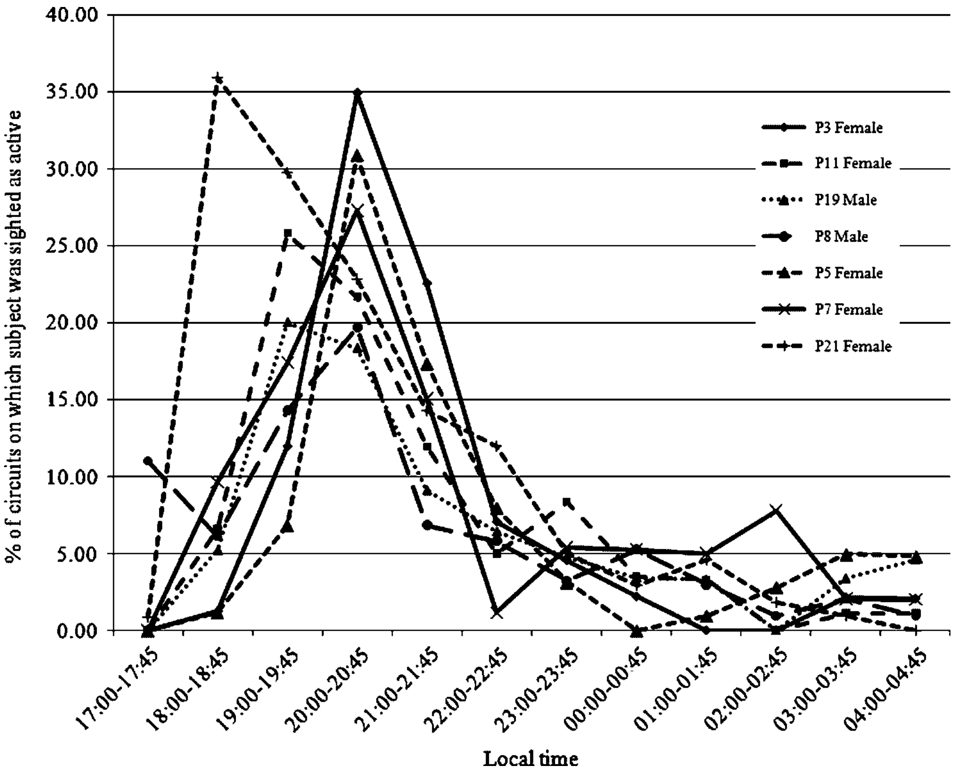

Fig. 3. Activity patterns.

Time spent *out of sight* by P11 and P19 is attributed to the subjects digging a burrow part way through the study, and opting to use that as opposed to the bed box, except on nights of intense rainfall. P3 also dug a burrow as temperature increased in the latter stages of the study and suggests that subjects used burrows as a more optimal environment for thermoregulation, as reported for the Chinese pangolin [Chen et al., 2005]. It further suggests that the species may lead a semi-fossorial lifestyle, excavating burrows, as well as utilizing tree hollows for resting [Duckwoth et al., 2009].

Differences in the time spent in procuring different food items in the study (e.g. between P11 and P19) could potentially be related to preferences for different prey species between subjects, which warrants future study. It was not surprising that P19 spent time in the behavioral category *mount* as juvenile pangolins are known to be "taxied" around on the back and tail of their mother. This may also account for the comparatively low proportion of time spent *walking* by this subject.

The time engaged in *social* behavior by P11 is a result of two instances of P11 and P19 wrestling. This involved the subjects rolling on the floor clawing at each other and on one occasion it lasted for 12 min. Claws making contact with scales were heard suggesting some level of aggression although the underlying cause and function of this behavior remains unknown. It was presumably a maternal interaction between P11 and its 4-month-old offspring. The age of independence in juvenile *M. javanica* is unknown but the total period of maternal care was estimated at 3 to 4 months by Lim and Ng [2007]. The observations of social interactions between these subjects support this assumption.

It is suspected that *resting* behavior is related to thermoregulation as it occurred toward the latter, hotter part of the study. In each of the three subjects in which this behavior was observed, it occurred with the subject resting at the artificial burrow entrance. The nature of *M. javanica* and observations of P21 inactive among Lychee branches (at 17:00 hr), after the study, suggests that arboreal bed boxes or artificial tree hollows might prove attractive as an alternative location for thermoregulation and refuge.

The enclosure of P3 was manipulated part way through the study in response to *clawing* behavior which was directed at the bamboo matting and chain link fencing, witnessed at an early stage in the study. Mats of decreasing height were removed over subsequent nights, the final piece being removed on 31 March. *Clawing* comprised a small proportion of the time-budget of P3 and after the final sheet of bamboo was removed this behavior ceased, a valuable experimental assessment. P8 and P21 directed the behavior toward the chain link fencing and P21 to the the metal door and door frame as well. The smaller enclosure housing P21 combined with no substrate for digging likely contributed to the *clawing* displayed by this subject. Blood found in the enclosure of P21 is evidence that this behavior can lead to superficial wounds on the face and foreclaws. Where possible efforts should be made to reduce the frequency of this behavior through enrichment such as the provision of rotting logs or artificial ant nests. In enclosures with rotting logs, ample soil and leaf litter, frozen and live ants or other food items could be scattered, potentially reducing *clawing* by appropriate redirection of the behavior. The offering of ants or other food items in multiple feedings throughout the active period and the use of alternative materials in the construction of new enclosures could also contribute to the cessation of this behavior.

Despite sizeable enclosures in the pangolarium, another ARB, *pacing*, was observed in three subjects (for definition see Table 2). This behavior has also been observed in the Chinese pangolin in captivity despite generous enclosures and the provision of a swimming pool [Schwindy, personal communication]. Periodically rearranging the enclosure furniture may help to reduce incidences of *pacing* while the enrichment suggested above may reduce the amount of time spent in this behavior as feeding would require more locomotion and more time spent searching for food.

Subjects were active intermittently over a period of 12 hr, in the period 17:00–05:00 hr. In contrast to a wild subject where activity peaked between 03:00 and 06:00 hr [Lim and Ng, 2007], peak activity occurred between 18:00 and 21:00 hr when considering all subjects. Notably different, the activity pattern of P21 peaks earlier than those of other subjects and was one of two subjects, the other was P8, that were observed to be waiting to be fed on occasion. Moreover, feeding behavior differed between subjects and from night to night. One night a subject would consume the majority of food in one sitting, on others it would leave and return to feed periodically, e.g. at 01:00 and 04:45 hr. The activity patterns presented here are similar to those reported for the Chinese pangolin by Heath [1987] and Heath and Vanderlip [1988]. In these studies, subjects were not active before 16:00 hr but were active over a 4–10 hr and a 10–11 hr period, respectively, with activity ceasing by 02:30 hr. However, as pangolin behavior is understood to change seasonally, it is a limitation of our study that it was undertaken over a short period of time.

Yang et al. [1999] suggest that more than one Chinese pangolin can be housed together. Two female Sunda pangolins, P5 and P7, were successfully housed together throughout this study and though they were reared together it is possible to house more than one female together without aggression [Nguyen Van et al., 2010]. However, it is suggested that male Sunda pangolins be housed in enclosures far enough apart to reduce any stress caused by olfaction. In sum, maintaining *M. javanica* remains problematic as it is suspected that close proximity to conspecifics in males, enclosure size, diet, and the presence of people can induce stress and contribute to fatalities [Clark, personal communication].

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions were drawn and recommendations made regarding captive care and management:

1. MANOVA analyses and individual time-budgets detailed idiosyncrasies in how subjects partitioned active time.
2. Two behaviors were recognized as ARBs throughout the study, *clawing* and *pacing*. The cessation of *clawing* in one subject was possible by modifying elements of its enclosure. Incidences of *clawing* behavior suggest alternative building materials should be considered for new enclosures. The provision of soil as a suitable substrate is also recommended for the design and construction of new enclosures.
3. *Pacing*, predominantly observed in one subject, involved the animal repeatedly following a route around its enclosure. The provision of rotting logs, scatter feeds and other novel feeding methods in addition to innovative methods of behavioral enrichment, could potentially redirect behavior and reduce incidences of both *clawing* and *pacing*.
4. Subjects were active intermittently over a period of 12 hr. Peak activity occured between 18:00 and 21:00 hr. Research investigating seasonal changes in behavior in captivity is recommended.
5. Future research should focus on but should not be limited to: stress levels (e.g. fecal or blood cortisol trials) and the exhibition of ARB including the redirection of locomotor stereotypies. Research into the captive behavior of Asian pangolins undertaken in the future should be disseminated between institutions maintaining the species.
6. Maintaining *M. javanica* in captivity remains problematic. Further improvements to captive environments that more closely approximate wild habitats should be sought, including trialling the provision of artificial tree hollows. Where maintained, subjects should be monitored closely and enclosures manipulated periodically in an attempt to mitigate stress and ARB.

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