Manchester Metropolitan University

MSc Conservation Biology

MSc Project – 61BL4161

Time-budgets and activity patterns of captive Sunda pangolins (*Manis javanica*)

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Abstract

This is the first assessment of *Manis javanica* captive behaviour. The aim of the investigation was to suggest ways of improving captive care and management by constructing active time-budgets and activity patterns and identifying any 'Abnormal Repetitive Behaviours' (ARBs). The effects on behaviour of rainfall, temperature, rH and moon phase were also investigated. Scan and focal animal sampling were used on seven subjects. Active time-budgets and correspondence analysis undertaken determined time spent in different behaviours differed between subjects. A MANOVA analysis resulted in an overall significant difference between how subjects allocated time between groups of behaviours (feeding, locomotion, hidden and other). Post hoc analysis detailed significant differences were not apparent between all subjects. Peak activity occurred between 18:00 and 21:00 h. There was little evidence of relationships between rainfall, temperature, rH or moon phase and time budgeted to specific behaviours. Four subjects displayed ARBs in more than one form and enclosure manipulation enabled the cessation of one ARB in one of two subjects. Recommendations are made pertaining to husbandry and captive management.

Keywords: Pholidota, captivity, behaviour, activity, husbandry, ARBs

Introduction

Pangolins (order: *Pholidota*; family: *Manidae*) are insectivorous mammals inhabiting tropical and subtropical forests, thick bush and open savannah regions in Africa and Asia (Nowak, 1991). One of the least diverse mammalian groups (Rose, 2001) *Manis* spp. are understood to 'represent an early radiation of the mammalian (eutherian) lineage occurring in the Cretaceous period' (Eisenberg, 1981). They exhibit an atypical morphological characteristic amongst mammals, the major parts of the body being covered in horny scales (Luo *et al*, 2007). Adaptations to a specialist diet of ants and termites (Sweeney, 1956; Kingdon, 1971; Smithers, 1983; Legakul & McNeely, 1988; Nowak, 1991, Swart *et al*, 1999) include no teeth, a long, sticky tongue for prey consumption, a conical shaped head and powerful long claws for digging and breaking apart ant nests or termite mounds (Payne *et al*, 1985; Payne & Francis, 1998). Thick skin, the ability to close ear and nostril openings and thick heavy lids protecting their eyes (Nowak, 1991) are further adaptations. It is reported *Manis pentadactyla* L. preys upon at least nine species of termite and six ant species (Wu *et al*, 2005).

The eight extant species of pangolin (Table 1) can be distinguished by differences in their anatomy, size, range (Heath & Vanderlip, 1988) and scales (Pocock, 1924). The African species are both smaller and larger than the Asian species and the presence of hair at the base of scales in the latter is a means of distinguishing between the two (Macdonald, 2006). Recent phylogenetic analysis proposed the Palawan Pangolin *Manis culionensis* D. as being a distinct species from the Sunda Pangolin *Manis javanica* D. and is endemic to Palawan and Culion in the Philippines (Gaubert & Antunes, 2005).

Terrestrial-fossorial species include *M. pentadactyla* (Allen, 1938), *Manis temminckii* S. and *Manis gigantea* I. (Macdonald, 2006). Arboreal species include *M. javanica* (Allen, 1938; Payne *et al*, 1985; Francis, 2007), *Manis tricuspis* R. and *Manis tetradactyla* L. (Macdonald, 2006) that have prehensile tails for support when climbing (Payne *et al*, 1985; Nowak, 1991; Francis, 2007). Rather than digging burrows it is understood arboreal species including *M. javanica* sleep in tree hollows

Table 1 The eight extant Manis spp. and 2008 IUCN Red List statuses

	Species		***2008 IUCN***
Location	***Common name***	***Scientific name***	***Red List category***
Asia	Sunda pangolin	*Manis javanica*	EN (A2d+3d+4d)
	Chinese pangolin	*Manis pentadactyla*	EN (A2d+3d+4d)
	Indian pangolin	*Manis crassicaudata*	NT
	Palawan pangolin	*Manis culionensis*	NT
Africa	Giant pangolin	*Manis gigantea*	NT
	Tree pangolin	*Manis tricuspis*	NT
	Cape pangolin	*Manis temminckii*	LC
	Long-tailed pangolin	*Manis tetradactyla*	LC

Source: IUCN 2008

(IUCN, 2008; Lim & Ng, 2007). All species are understood to be solitary, though it is suggested adults sometimes associate in pairs (Nowak, 1991). All species are understood to be nocturnal (Nowak, 1991; Heath, 1987; Macdonald, 2006; Roberts, 1977; Boonsong Lekagul & McNeely, 1977; Davies & Payne, 1982; Foenander, 1953; Medway, 1969 and Medway, 1977; Heath & Vanderlip, 1988), though diurnal activity has been observed (e.g. Jacbosen *et al*, 1991; Lim & Ng, 2007) and this suggests some variability in daily activity patterns between individuals (Richer *et al*, 1997).

The status of all *Manis* spp. has recently been revised as part of the IUCN's GMA (Global Mammal Assessment). *Manis javanica* was upgraded to endangered (Table 1). The Asian species are listed on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 2008) with a zero annual export quota established for specimens removed from the wild and traded for primarily commercial purposes (CITES, 2008). Pangolins are listed as 'specially protected animals' in most of their range states (Brautigam *et al*, 1994; Sodeinde & Adedipe, 1995; Richer *et al*, 1997; Wu, 1998; Nowak, 1999; Misra & Hanfee, 2000; Wu *et al*, 2002).

International trade in skins, scales and meat and the loss and deterioration of available habitat are threats to Asian pangolins (CITES, 2000). They are consumed as food in Vietnam and China (ENV, 2007) and their scales are thought to be a powerful medicine in modern TCM (Traditional Chinese Medicine) (Ellis, 2005). Pangolins are commonly traded species (World Bank, 2005) and *M. javanica* as well as *M. pentadactyla* 'are considered the most traded mammals in Asia, with thousands being illegally hunted and traded across international borders each year' (TRAFFIC Southeast Asia, 2004). Indiscriminate hunting throughout most of their range (Luo *et al*, 2007) is a threat amplified by the fact the species are prone to the effects of over-harvesting (Lim & Ng, 2007). All available evidence suggests that pangolins are disappearing throughout their natural range in Asia as a result of trade (World Bank, 2005a). Despite evidence suggesting pangolins can adapt to modified habitats such as secondary forest (CITES, 2000), the destruction of habitat is a reason pangolin numbers have declined dramatically (Nowak, 1991; Wu, 1998). It is a factor reported to have affected the status of *M. pentadactyla* and *M. javanica* in some range states

(CITES, 2000) and WCMC *et al* (1999) report that the replacement of natural forest with oil palm monocultures is a major threat to *M. javanica*.

Manis javanica is distributed across the forests of Southeast Asia and Indonesia (Gaubert & Antunes, 2005). Its range extends from southern Myanmar, through Laos, Thailand, central and southern Vietnam, Cambodia, to peninsular Malaysia, to Sumatra, Java and adjacent islands to Borneo (Malaysia, Indoneisa, Brunei) (Schlitter, 2005). The species inhabits primary and secondary forest (CITES, 2000; IUCN, 2008) but also occurs in cleared and cultivated areas including gardens and rubber plantations (CITES, 2000). There are no detailed studies on population levels, ecology or life history of this species despite its relatively wide distribution (Lim & Ng, 2007) making it difficult to assess the impact of harvesting (CITES, 2000). Much of what is known about *M. javanica* is considered anecdotal (Lim & Ng, 2007).

Despite having been maintained in various zoos prior to 1970, pangolins are now exhibited infrequently (Yang *et al*, 2007) and are among the rarest of zoo specimens (Wilson, 1994) (Table 2). Known rescue centres maintaining pangolins have been included in Table 2. Hoyt (1987) reported pangolins do not survive well in captivity; mortality rates of 71% in the first year and up to 89% after two-and-a-half years are reported. Success in maintaining arboreal species in captivity has been extremely limited (Heath & Vanderlip, 1988). Jones (1977) reported that an individual *Manis crassicaudata* G. was maintained in captivity for at least 12 years and eight months to 1 September 1978 while Wilson (1994) reports individuals have been held in captivity for up to 19 years. These cases must be considered exceptional and although it has been suggested that pangolins can be easily maintained in a captive environment (Heath & Vanderlip, 1988) general consensus is that this is difficult (Crandall, 1964; Tenaza & Schultz, 1977; Yang *et al*, 2007).

It is understood pangolins removed from the wildlife trade develop gastric stomach ulcers as a result of stress induced by trade, which when combined with the stress of a captive setting can be fatal (Clark, L. pers. comms). The cause of stress in captivity is unknown though it is suspected subjects need time to adjust to the presence of people (keepers, vets) (Clark, L. pers. comms.). Being maintained in too close a proximity to conspecifics (Clark, L. pers. comms.), a sub-optimum diet (Nguyen Van, T. pers.

comms.) and inappropriate enclosure sizes are factors suspected to induce stress. Of the *M. pentadactyla* individuals that have been reared in captivity, most have died from gastrointestinal problems and it is suggested no more than three should be housed together (Yang *et al*, 1999).

Longevity in captivity has increased recently at certain institutions as a result of improved captive diets (Yang *et al*, 2007) but a lack of research means there is little knowledge of captive behaviour (Chen *et al*, 2005). Yang *et al* (2007) have reported on the history and dietary husbandry of pangolins while Wilson (1994) has discussed husbandry pertaining to *Manis* spp. more broadly. Chen *et al* (2005) investigated activity patterns of captive *M. pentadactyla* and suggested soil burrows provide a suitable environment for thermoregulation. Heath (1987) and Heath and Vanderlip (1988) reported on biology, husbandry and veterinary care of *M. pentadactyla*. The study reported strictly nocturnal behaviour, with subjects usually leaving their bed boxes after 16:00 h and returning intermittently before the cessation of activity by 02:00 h. Pangolins remained outside the bed box for periods from 30 s to 1.5 h and how much time was spent outside of the bed box differed from one individual to the next on any given night. Heath & Vanderlip (1988) suggested an area of 12-14 m² as sufficient for 3-4 pangolins, but reported 3-4 m² was too small. Heath (1987) reported activity patterns were consistent from one day to the next for individuals but there were differences between individuals. Females showed more activity over a longer period of time than males (Heath 1987). Heath & Vanderlip (1988) reported maintaining a juvenile *M. pentadactyla* was problematic partly because of apparent high levels of energy and activity.

Time-budgets

The proportions of time animals spend in different behaviours; the ‘time-budget’ varies greatly across different taxa (Bernstein, 1976) and within a species according to age, sex, and season (Grubb & Jewell, 1974). Time is divided between behaviours which allow animals to satisfy their basic requirements; food, movement and rest (Bernstein, 1976) but is also related to factors such as energy requirements for growth and homeostasis (Samson & Raymond, 1995).

Activity patterns

Information about an animal’s activity pattern is important for understanding behaviour (Weller & Bennett, 2001) and can aid in assessing the housing and husbandry practices employed (Heath & Vanderlip, 1988). Producing baseline data on when captive subjects are active and how active time is partitioned will permit an understanding of behaviour and be conducive to making recommendations for future captive care and management. Through the study of both captive and wild subjects it is possible to determine whether the captive setting is conducive to the expression of species-typical behaviour (Maple & Perkins, 1996).

Environmental variables

The lunar cycle is understood to influence the activity pattern of nocturnal mammals (Elangovan & Marimuthu, 2001) and it is suggested that pangolin behaviour is related to both the lunar cycle (Clark, L. pers. comms.) and rainfall (hunters reports suggest that pangolins are more easily detected in the rainy season) (Newton *et al*, 2008).

Abnormal Repetitive Behaviour

The term ‘Abnormal Repetitive Behaviour’ (ARB) has been suggested by Garner (2008). It conveys nothing about causation and is suggested as appropriate for use where the cause of repetitive behaviour, or stereotypic behaviour, defined as invariant behaviours performed repetitively with an apparent lack of function (Ödberg, 1978; Mason, 1991) is unknown (Mason *et al*, 2007). This is understood to be particularly true for zoo animals due to the lack of research conducted (Mason *et al*, 2007). The term was applied to this study. Stereotypic behaviour has been observed in captive *M. pentadactyla* in the form of pacing behaviour (Clark, L. pers. comms.).

Aims and objectives

It is hoped that this study will contribute to an understanding of the captive behaviour and conservation of *M. javanica*. The aim of the investigation was to assess the behaviour of captive *M. javanica* in order to suggest ways of improving care and management. The objectives were to: (1) determine active time-budgets and activity patterns; (2) ascertain whether the effects of rainfall, temperature, rH and/or moon phase affected time-budgets, it is hoped this study may elucidate relationships between these variables, and (3) determine whether individuals displayed ARB behaviours.

Table 2 Institutions known to be holding Manis spp.

Institution	*Location*	*Species*	*No.*[a]	*Date (source)*	*Source*
Zoological Collection					
Taipei Zoo	Taiwan	*M. pentadactyla*	15	24/10/07	Pers. comms.
Night Safari	Singapore	*M. javanica*	3	2/7/08	Pers. obs.
Zoo Leipzig	Germany	*M. pentadactyla*	1	27/10/08	ISIS[e]
San Diego Zoo	U.S	*M. tricuspis*	1	27/10/08	ISIS[e]
Ueno Zoo	Japan	*M. pentadactyla*	1	27/10/08	ISIS[e]
Rescue Centre					
CPCP[b]	Vietnam	*M. javanica*	7	2/7/08	Pers. comms.
ACCB[c]	Cambodia	*M. javanica*	1	2/7/08	Pers. comms.
Tikki Hywood Trust	Zimbabwe	*M. temminckii*	0[d]	23/7/08	Pers. comms.

[a] Sexes of all individuals not known so total stated.
[b] Carnivore and Pangolin Conservation Programme.
[c] Angkor Centre for the Conservation of Biodiversity
[d] It is known this institution has maintained *M. temminckii* in recent years.
[e] International Species Information System (2008)

Methods

Location

The study was undertaken at the Carnivore and Pangolin Conservation Programme (CPCP) facility located at Cuc Phuong National Park, (20°14' - 20°24'N, 105°29' - 105°44'E; Birdlife, 2008) Vietnam. The range of *M. javanica* in Vietnam is restricted to central and southern provinces (Newton *et al*, 2008); consequently the study was conducted on subjects maintained outside their natural range. The study was undertaken over 34 nights between 23 March and 26 April 2008.

Subjects

All subjects were confiscated from the wildlife trade in Vietnam and comprised five adult females, one adult male and one juvenile male (Table 3). Ages remain unknown. All subjects were wild born with the exception of P19, born at the CPCP on 22 November 2007. Subjects P5 and P7 arrived at the CPCP at a young age; P7 was hand-reared.

Subjects P3, P8 and P21 were housed individually, P11 and P19 and P5 and P7 were housed together respectively (Table 3). The difference in size meant P11 and P19 were easily distinguished. P5 and P7 could not be distinguished by morphological differences so P7 was marked using tipex (Solvent based correction fluid; 1,1,1, trichloroethane) applied to scales which allowed identification.

Housing and enclosures

The 'Pangolarium' at the CPCP comprised four enclosures T1-T4 each measuring 29 m^2. Six subjects were housed in the pangolarium (Table 3). Enclosures measured 4.1 m in height including a soil depth of 1.0 m, 0.5 m of which was above ground level. Omitting soil depth, enclosures were 3.1 m in height, two sides of which were comprised of a concrete wall 1.8 m high with 1.8 m high 2" chain link fencing on top. This material was also used as a ceiling. A tiled apex roof covering 2.5 m of the 6 m wide enclosures provided each enclosure with partial cover. The inner wall of each enclosure facing an interior keeper corridor was comprised of 2" chain link fencing. Bamboo matting and sheets of mica had been added to the chain link fencing in an

Table 3 ID, sex, life stage, rearing condition, acquisition date, source, weight and enclosure of the study subjects

ID#	*Sex*	*Life stage*	*Rearing condition*	*Acquisition date*	*Source*	*Weight (kg)*[a]	*Enclosure*
P3	♀	Adult	Mother	9/10/06	Confiscated	3.65	T1
P5	♀	Adult	Mother	11/12/06	Confiscated	3.4	T4
P7	♀	Adult	Hand	11/12/06	Confiscated	3.85	T4
P8	♂	Adult	Mother	11/12/06	Confiscated	5.05	T3
P11	♀	Adult	Mother	Unknown	Confiscated	3.9	T2
P19	♂	Juvenile	Mother	-	22/11/07 [b]	0.7	T2
P21	♀	Adult	Mother	25/12/07	Confiscated	2.05	Q2

[a] Weights recorded: P5 (27/1/08), P19 (17/2/08), P21 (17/3/08), P3, P7, P8, P11 (21/3/08)

[b] D.O.B., Lineage: P11 x Wild male.

effort to reduce stress related behaviour prior to the study. It was suspected that subjects were stressed because of their close proximity to conspecifics. The side of enclosures backing onto adjacent enclosures were comprised of concrete. All enclosures contained one sunken concrete burrow (T1 had two) with drainage pipes acting as burrow entrances. Burrows were lined with wooden bed boxes; approximately 1.0 m in length x 0.5 m x 0.5 m. Bed boxes contained dried leaf litter as a bedding material, a suitable alternative to sand (Heath & Vanderlip, 1988).

Enclosure Q2 measured 1.95 m in height by 1.85 m x 2.85 m (5.2 m^2). Leaf litter was added on occasion providing a preferable substrate to concrete. All enclosure sides were concrete walls with a 1” chain link fence ceiling. One side comprised a metal door and two openings which led to bed boxes, one at ground level and one approximately 0.5 m above ground level. The door to the enclosure was solid apart from the top quarter that was comprised of metal bars approximately 1” apart. Partial cover was provided by a tiled apex roof.

All enclosures contained furniture consisting of branches of varying diameters from native tree species. Enclosures T1-T4 had more furniture than Q2, not only because of the size difference but the soil substrate allowed native flora to be cultivated. Whereas enclosures T1-T4 had areas of dense vegetation, Q2 was limited to a network of branches. Heat mats provided throughout the winter months maintained bed box temperatures at 23°C. These were removed on April 9, approximately half way through the study, due to increases in temperature. In enclosures containing two bed boxes (T1 and Q2), one bed box contained a heat mat.

Nocturnal observations were made possible by red light illuminating the enclosures. Enclosures T1-4 were illuminated by two 100W bulbs in each enclosure painted red [TV quick drying Aerosol, A211 ‘Red’ Công Ty U. R. Chemical (Viêt Nàm) TNHH]. Q2 was illuminated by one. This method has been used previously (Finley, 1959; Elangovan & Marimuthu, 2001) and been advocated for observing nocturnal species (e.g. Finley, 1959). Red lights illuminated the enclosures for the duration of ten nights (from 13 March 2008) prior to the study commencing to allow subjects a period of adjustment to increased light levels.

Whether red light is visible to *Manis spp.* is unknown. It is suspected pangolin retinas like those of other nocturnal mammals are dominated by rod photoreceptor cells (Rodieck, 1973). If pangolin retinas, like those of most vertebrates, have cone photoreceptor cells as well (Finley, 1959; Rodieck, 1973), it means the low stimulus of red light would have been less disturbing than white light (Finley, 1959).

Husbandry

Enclosures were spot cleaned on a daily basis and fresh water provided on an *ad libitum* basis. Certain subjects were known to defecate in the same location and bury faeces; others were known to defecate in water bowls. Two water bowls (~60 cm in diameter, ~15 cm deep) were provided, approximately 1/3 full in enclosures T1-T4 one of which was used for defecation and provided an alternative to litter trays (Heath & Vanderlip, 1988).

Subjects were offered food in three ways dependent upon the availability of native ant species within and around Cuc Phuong National Park. Live weaver ants (*Oecophylla smaragdina* F.) were offered in metal feeding bowls (the equivalent in Q2 was concrete) measuring 95 cm in diameter. The bowls contained a moat to prevent ants escaping. *O. smaragdina* were collected in the morning from local forests and material such as leaves from nests was offered allowing subjects to forage. *O. smaragdina* collected in the morning and frozen prior to feeding were also offered in porcelain bowls to ensure sufficient food was provided. Nests of *Crematogaster* spp. E. were offered on a daily basis having been harvested from local forests and allowed for species typical behaviour, i.e., breaking into ant nests. Subjects were offered fresh ants daily; all food types being placed in enclosures between 17:30 and 18:00 h. *Crematogaster* spp. nests were not offered on the first three nights of the study.

Data collection and statistical procedures

Time-budgets

Two observers collected data, the author plus a local researcher (Nguyen Van Thai). One observer undertook data collection from 17:00-23:00 h and the second from 23:00-05:00 h each night.

The study focused on behavioural states, identified from preliminary observations over seven nights between March 3 and 22. The 14 states, defined in operational terms (Martin & Bateson, 2007) and five super category behaviours (Forthman & Bakeman, 1992) formed the ethogram used, shown in Table 4. Behaviours were both exhaustive and mutually exclusive (Bakeman & Gottman, 1997). The behaviour ‘clawing’ (X, Table 4) is understood to be an indicator of stress (Ngyuen Van Thai, pers. comms.) and meets the definition of an ARB.

To provide an exact record of time at which behavioural states began and ended (Martin & Bateson, 2007) the continuous recording method was implemented using an Olympus Digital Voice Recorder. Behaviours witnessed throughout the study but not previously observed were recorded as other.

Commencing at 17:00 h scan samples (Altmann, 1974) were undertaken to determine if subjects were active. The last scans were undertaken at 04:30 h or 04:45 h dependent on subject activity. Each subject was scanned during a walk past each enclosure in a predetermined order. Each night of observations started with a different circuit and subject scanned first. Subjects which were housed together were scanned for first alternately.

During anyone circuit the first subject sighted as being active was the subject of a 15 min focal animal sample (Altmann, 1974) but this was commenced after all subjects had been scanned. If a subject not previously sampled that night was active, that subject was the focus of the sample. Where more than one subject not already sampled on that night was sighted as active, the first subject sighted on that circuit was the focus of the focal animal sample. On consecutive circuits, if no subject was active apart from the subject last sampled that subject was sampled again. Subjects sighted as being active on circuits but no longer active when returned to were no longer the subject of the focal animal sample. Focal animal samples finished when 15 min had elapsed. 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 for 15 min.

A subject was considered to be active when it could be seen or it was evident it was active, for example if it was foraging for *O. smaragdina* in the food bowl. If a subject was active but couldn't be identified (e.g. if it was within vegetation), it was used for the focal animal sampling as long it was identifiable when the sampling actually took place. Pangolins are known to sleep in bed boxes in captivity (Heath & Vanderlip, 1988) though whether other behaviours are exhibited there is unknown. Consequently, a subject was not considered active if it was heard moving or rustling in the bed box.

Frequent power cuts occurred over the duration of the study so observations were made by torches sprayed with red paint. These samples were excluded from analyses as it was suspected that the movement of the torch may have adversely affected the behaviour of the subjects. P19 escaped from T2 on 23 and 25 March through the chain link fencing so samples for these dates were omitted for P19 and P11.

The proportions of time subjects spent in behavioural states and descriptive time-budgets were extracted from audio files using RecorderV software [RecorderV, courtesy of Dr Les May, Manchester Metropolitan University]. Samples were excluded where subjects were observed as 'out of sight' (O, Table 4) for more than 600 s (10 min). This avoided analysing samples where the majority of the behaviour was unknown. Time spent out of sight was omitted from analysed samples for the same reason and data were standardised to 900 (15 min) to account for this. The mean (and standard error) proportion of active time spent in each behavioural state were calculated for each subject.

Correspondence analysis (Fisher, 1940; Lebart & Fenelon, 1971; Benzecri, 1973; Hill, 1974) was conducted on mean time-budgets in a contingency table to explore

Table 4 Ethogram of M. javanica behaviours used in this study.

Super category	*Key*	*Behavioural 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 seconds).
	(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 seconds).
	(E)	**Black ants –** Individual intersperses brief use of forelimbs to break into ant nest and sticks out tongue to consume *Crematogaster* spp.
	(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 seconds) and/or brief use of forelimbs (less than 3 seconds) to touch/move substrate.
	(C)	**Climbing** – Individual uses 2 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 seconds).
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 is out of sight and its behaviour is unknown.
	(B)	**Bed box –** Individual is in the bed box or tunnel to the bed box and its behaviour 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 seconds 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 behaviour not included in this ethogram e.g. time taken to defecate, clean or spend in water.

potential differences between subjects. This method was used because it has been implemented in the analysis of time-budgets previously (e.g. Boy & Duncan, 1971) and produces a visualisation of relationships between subjects and behaviours. It also details the percentage of variation maintained on each axis (Boy & Duncan, 1971) and 'analogous to the loading of a variable in principal component analysis (Kendall & Stewart, 1968), gives a basis for the interpretation of the biological meaning of the axes'. The analysis was undertaken using Minitab (Minitab ver. 15).

To test for significant differences in time allocated to super category behaviours between subjects a MANOVA was conducted. The analysis was undertaken in PAST (Paleontological Statistics ver. 1.81) software which allowed for an analysis of variance despite different samples sizes for each subject. To compare the amount of time spent in super categories between all subjects, social and mount behaviours were grouped into 'other'. Log ratio analysis allowed data to be freed from the constraint that percentages necessarily sum to 100% with the result that individual measures are not independent. Conversion to log ratios ensured that the measured variables are independent of one another. Where zeros were present as the denominator or numerator, one was added to both. The parametric MANOVA was used because all transformed data for each super category approximated a normal distribution. 'Other' behaviour was chosen as the denominator as it was considered less important than feeding, locomotion or hidden in analysing time-budgets. Standardising data to 900 to exclude the behaviour out of sight means the super category, 'hidden', is comprised solely of the behaviour 'bed box'.

ARBs

By continuously recording the behavioural state of subjects throughout focal samples observations that fitted the definition of an ARB as defined by Garner (2008) were noted for discussion.

Enclosure manipulation

Enclosures housing P3 and P21 were manipulated part way through the study in response to clawing behaviour witnessed in preliminary observations (P21) or early data collection (P3). Q2 which housed P21 was manipulated by rearranging the network of branches on 9 April; a branch was positioned so that climbing to the ceiling fencing was possible. P3 had been observed clawing at the bamboo matting in early focal samples. Mats of decreasing height were removed over subsequent days, the final piece removed on 31 March exposing only chain link fencing.

The durations of time spent clawing prior to and post manipulation extracted from audio files were noted.

Activity patterns

Scan samples undertaken determined if subjects were active at intervals of 15 or 30 min for the duration of each night (17:00-05:00). Activity patterns were constructed by calculating the proportion of circuits on which subjects were active per time period (e.g. 17:00-17:45 h). Nights where a subject was never sighted as active were omitted from analyses pertaining to that subject. Where a subject could not be identified, e.g. P5 or P7, circuits were excluded from analyses.

Environmental variables

Temperature and rH

Temperature and rH were recorded each hour between ten to and ten past the hour using a hygrometer [Testo 610 New Hygrometer]. This enabled one observer to undertake scan and focal samples and collect data on environmental variables. The hygrometer was located in close proximity ($\leq$25m) to all enclosures under a tiled apex roof to protect it from the tropical weather. On occasion temperature and rH readings were not taken within the time frame stipulated. To account for this the median for the night was taken and used to replace missing data. Means were calculated for each night and used in the analysis.

Rainfall

Rainfall was recorded at 17:00 h prior to, and at 05:00 h, post each night of observations using a rain gauge [Invicta Rain Gauge (Ref: 0840)]. The rain gauge was secured in the ground at ~5 cm above ground level.

Moon phase

The lunar cycle was split into primary phases based on the percentage of lunar disk illuminated, a method used previously (e.g. Lang *et al*, 2005; Dixon *et al*, 2006). The phases were: new moon (<25 % - <25 %), first quarter (≥25 % - ≤75 %), full moon (≥75 %) and third quarter (<75 % - >25 %). To avoid observer bias each observer undertook data collection on an equal number of nights and an equal number of early and late observation periods (17:00-23:00 h and 23:00-05:00 h) per lunar phase. Where an odd number of nights were present each observer undertook data collection for one period. One observer estimated cloud cover each night. Nights were categorised as clear, with some cloud or cloudy.

To investigate the proportion of time spent in behaviours of interest in relation to temperature, rH, rainfall, moon phase and cloud cover multiple linear regressions and Pearson's correlation were used to explore linear relationships. Non linear regressions were used to explore non-linear associations. Analyses were undertaken on all focal samples ($n = 252$). Behaviours of interest were 'walking', 'climbing' and 'clawing'. In light of Newton *et al* (2008) who suggested pangolins are more easily detected by hunters in the rainy season, potentially because they are more active, 'walking' and 'climbing' behaviours were analysed. 'Clawing' was analysed in an attempt to explore whether the behaviour could be linked to environmental conditions.

To ensure the measured variables were independent of one another in the multiple linear regressions, the proportion of time spent in behaviours was arcsine transformed, after division by one hundred so the resulting data were near normally distributed (Zar, 1999), as follows –

$$p = \arcsin \sqrt{p}$$

Multiple linear regression analysis was undertaken in Minitab (Minitab ver. 15) to explore potential linear relationships between the three behaviours and temperature, rH and rainfall. Spearman's rank correlation was used to explore linear relationships between moon phase and cloud cover and 'walking', 'climbing' and 'clawing'. The analysis was undertaken in Minitab. The proportions of time spent in the behaviours by all subjects were ranked so correlation coefficients could be calculated.

Non linear regression analysis exploring curve estimations was undertaken on the proportion of time spent in behavioural states by subjects against the environmental variables. This analysis was undertaken to explore non-linear relationships and was conducted in SPSS (SPSS ver.16.).

Observer reliability

Cohen's Kappa coefficient was used to assess inter-observer reliability allowing for chance agreements between observers (Bakeman & Gottman, 1997; Martin & Bateson, 2007). Four assessments were undertaken on an *ad libitum* basis on the final dates of preliminary observations prior to the study commencing. Each assessment was undertaken by observing one subject for a 15 min focal animal sample with the behavioural state the subject was in recorded every 15 sec with the aid of an audio cue [Zen recorder files courtesy of Dr Les May, Manchester Metropolitan University;]. The proportion of agreement observed (P_{obs}) and the proportion of agreement observed by chance (P_{exp}) were calculated allowing Kappa's *K* statistic as follows -

$$K = \frac{P_{obs} - P_{exp}}{(1 - P_{exp})}$$

As a result of frequent power cuts causing disturbance to observations and in order to maximise data collection, observer-agreement assessments were undertaken on an *ad libitum* basis three times throughout the study.

Results

Descriptive time-budgets

The percentage of time spent out of sight during observations varied between subjects. P21 spent the lowest percentage of time ‘out of sight’, 0.1 ± 0.1 % (*n* = 53). In contrast, P11 and P19 were ‘out of sight’ for >10 % of time spent observing, 17.3 ± 4.5 % (*n* = 24) and 11.4 ± 3.6 % (*n* = 19) respectively. The remaining four subjects spent similar proportions of time ‘out of sight’, P3 (7.2 ± 2.2 %, *n* = 34), P5 (4.5 ± 1.1 %, *n* = 36), P7 (4.4 ± 0.9 %, *n* = 47) and P8 (3.0 ± 0.8 %, *n* = 39).

The percentage of time spent in the different behavioural states (excluding out of sight) is shown in Figure 1. P11 displayed the highest percentage of time spent feeding on ‘frozen ants’ (*O. smaragdina*), 28.1 ± 5.5 %, and the least percentage was exhibited by P5, 5.8 ± 1.7 %. P3 exhibited the greatest percentage of time allocated to feeding on ‘live ants’ (*O. smaragdina*), 10.6 ± 2.4 % in contrast P7 which spent the lowest, 2.8 ± 0.9 %. P19 spent 27.5 ± 7.8 % of active time procuring *Crematogaster* spp. (‘black ants’), more than double the amount of any other subject. All subjects exhibited similar, marginal percentages of time spent ‘drinking’ (min. = P11, 0.2 ± 0.2 %; max. = P7, 2.0 ± 0.6 %; *n* = 7). Time allocated to all behaviours towards the procurement of food and water (F, L, E and Y, super-category ‘Feeding’) varies between subjects, ranging from 21.8 ± 2.8 % (min. = P7) to 43.5 ± 6.5 % (max. = P11; *n* = 7, range = 22 %; Figure 2).

The greatest percentage of time spent ‘climbing’ was exhibited by P21, 32.3 ± 4.0 %, followed by P3 that spent 20.7 ± 4.3 % in this state. P11 spent the least amount of time in this behaviour (7.3 ± 2.6 %), marginally less than P8 (7.8 ± 3.2 %). The percentage of time spent ‘walking’ ranged from 4.94 ± 1.09 % (P19) to 21.8 ± 3.3 % (P11). ‘Digging’ was observed in all individuals with the exception of P21 whose enclosure did not have any soil. Time spent ‘digging’ ranged from 0.1 ± 0.1 % (P7) to 4.1 ± 2.2 % (P3). Although ‘digging’ comprised only a small percentage of the time-budget of P3, it was over eight times the percentage of time spent digging by all other subjects and comprised <1 % of their active time. Time spent ‘paused’ ranged from 1.5 ± 0.6 % (P8) to 7.3 ± 3.2 % (P5).

Figure 1 Descriptive time-budgets, Mean ± SE of % of time spent in behavioural states

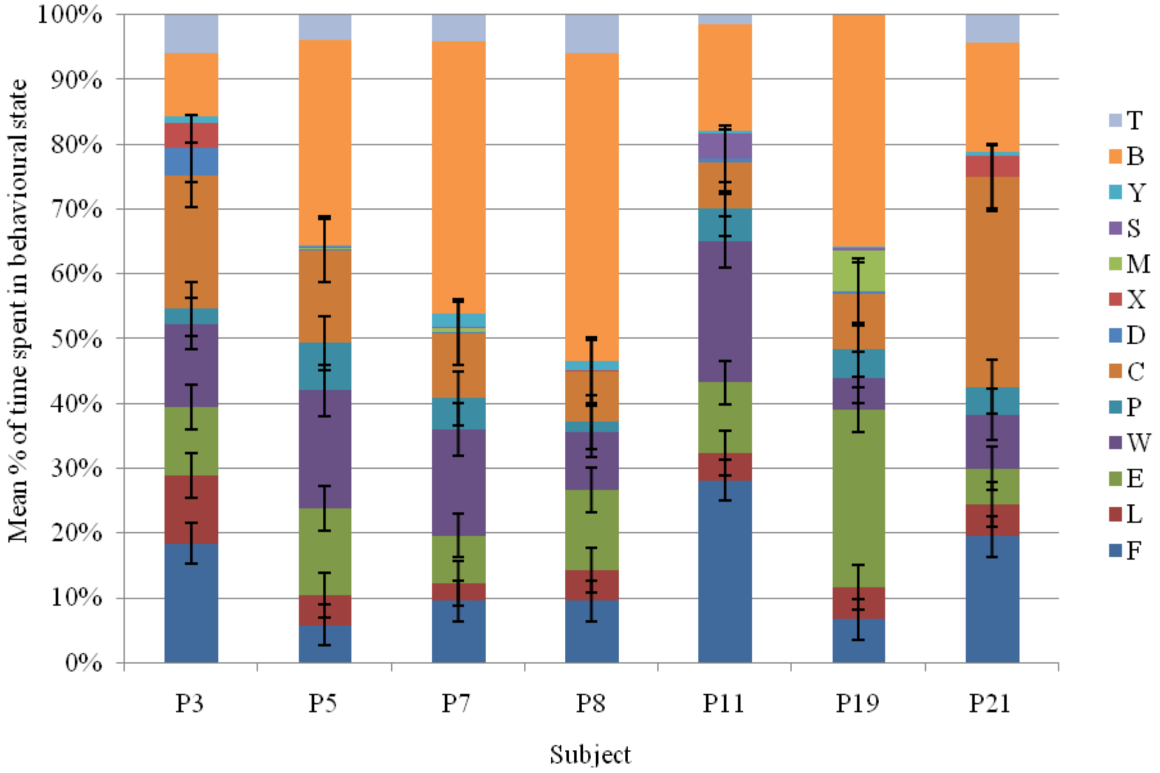
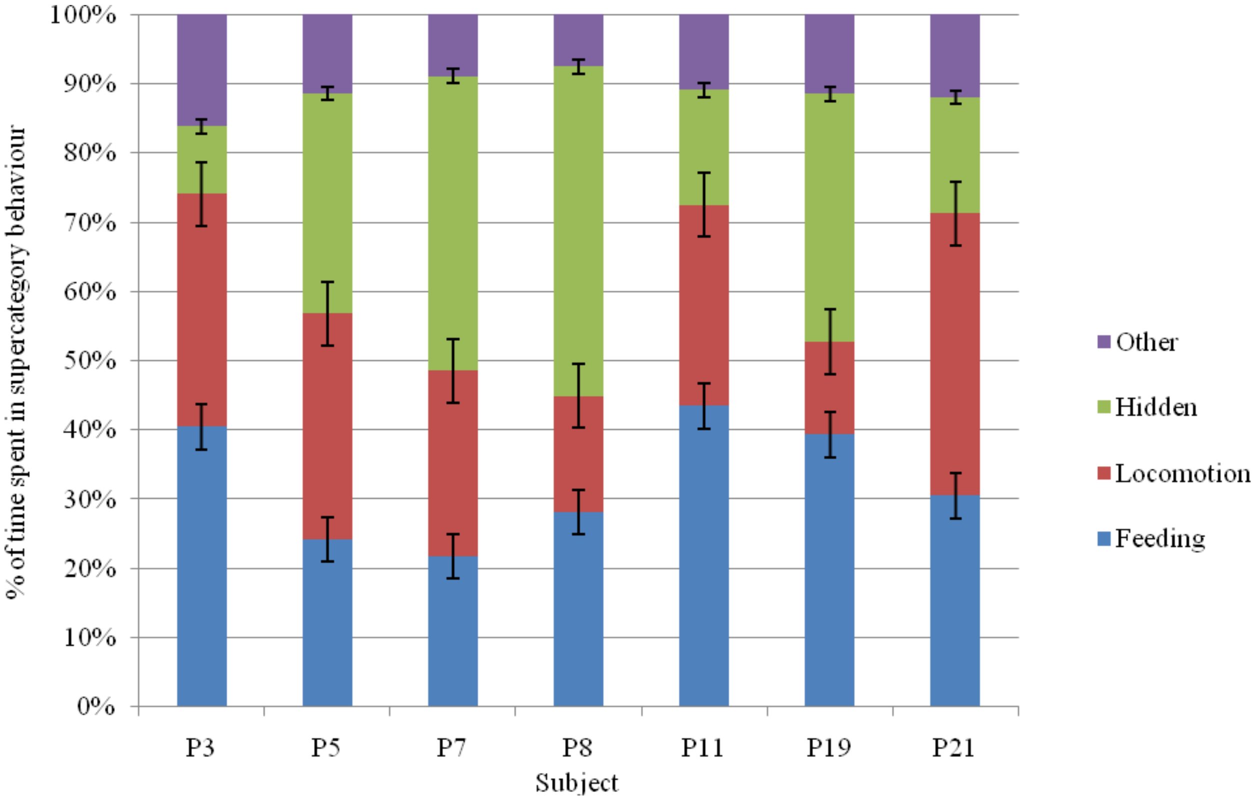


Figure 2 Descriptive time-budgets, Mean ± SE of % of time spent in behavioural super categories



‘Clawing’ behaviour was exhibited by three subjects, P3, P8 and P21. It comprised a relatively small percentage of the active time for P3 and P21 (3.9 ± 2.1 % and 3.4 ± 1.6 % respectively) and much less for P8 (0.07 ± 0.07 %).

Three of the four subjects housed with a conspecific displayed ‘mount’ behaviour, the exception being P11. The highest proportion of time spent in this state was P19, the juvenile, which spent 6.4 ± 2.5 % of active time mounted on the back and tail of P11. Subjects P5 and P7 spent <1 % of their active time in this state. All four subjects, P5, P7, P11 and P19 exhibited ‘social’ behaviour other than mount. Subjects P5 and P7 spent <1 % in this state, as did P19. The figure for P11 was 3.9 ± 3.9 % of active time.

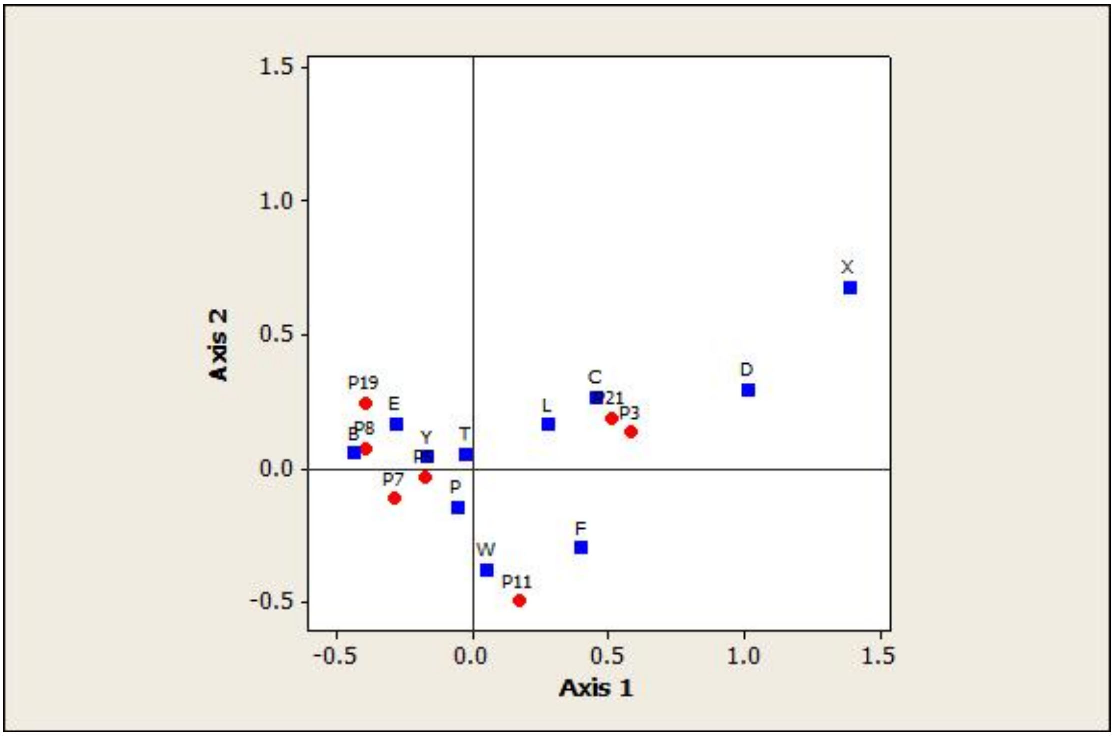
Time spent in the ‘bed box’ constituted approximately one third of the active time-budgets of P5 (31.8 ± 5.2 %) and P19 (35.8 ± 8.4 %). The time-budgets of P7 and P8 were dominated by this state; constituting 42.5 ± 4.7 % and 47.5 ± 4.7 of their active time respectively. Time spent in ‘other’ behaviour ranged from 0.0 ± 0.0 % (min. = P19) to 5.9 ± 2.6 % (max. = P8).

Correspondence analysis ordinations (Figure 3) illustrate relationships between subjects and behaviours. The total variation maintained on the first two axes was 70.9 % and this was increased to 85.7 % by the inclusion of the third axis (Table 5). The derived variables giving the position of behaviours and the contribution of behaviours to each axis are presented (Table 6). Axis 1 is mainly loaded by ‘climbing’ and ‘bed box’. Axis 2 is mainly representative of ‘frozen ants’, ‘climbing’ and ‘walking’ and Axis 3 of ‘black ants’ (feeding on *crematogaster* spp.), ‘climbing’ and ‘digging’.

P3 is affiliated with ‘climbing’ on the first ordination (Figure 3a) but with the inclusion of the third axis is more closely affiliated with feeding on live *O. smaragdina.* P5 and P7 are close to ‘paused’, ‘bed box’ and ‘drinking’ but are close to zero on both axes suggesting balanced time-budgets. P8 is also close to zero on both axes suggesting a balanced time-budget but the subject also shows an affiliation with the behaviour ‘bed box’. P11 is close to zero on axis 3 but is at the extreme end of axis 2 suggesting time is spent ‘walking’ and feeding on frozen *O.smaragdina*

Figure 3 Correspondence analysis ordinations for subjects. Blue squares are behaviours, red circles are subjects.

(a) Axis 1 (C, B) and 2 (F, C, W)



(b) Axis 2 (F, C, W) and 3 (E, C, D)

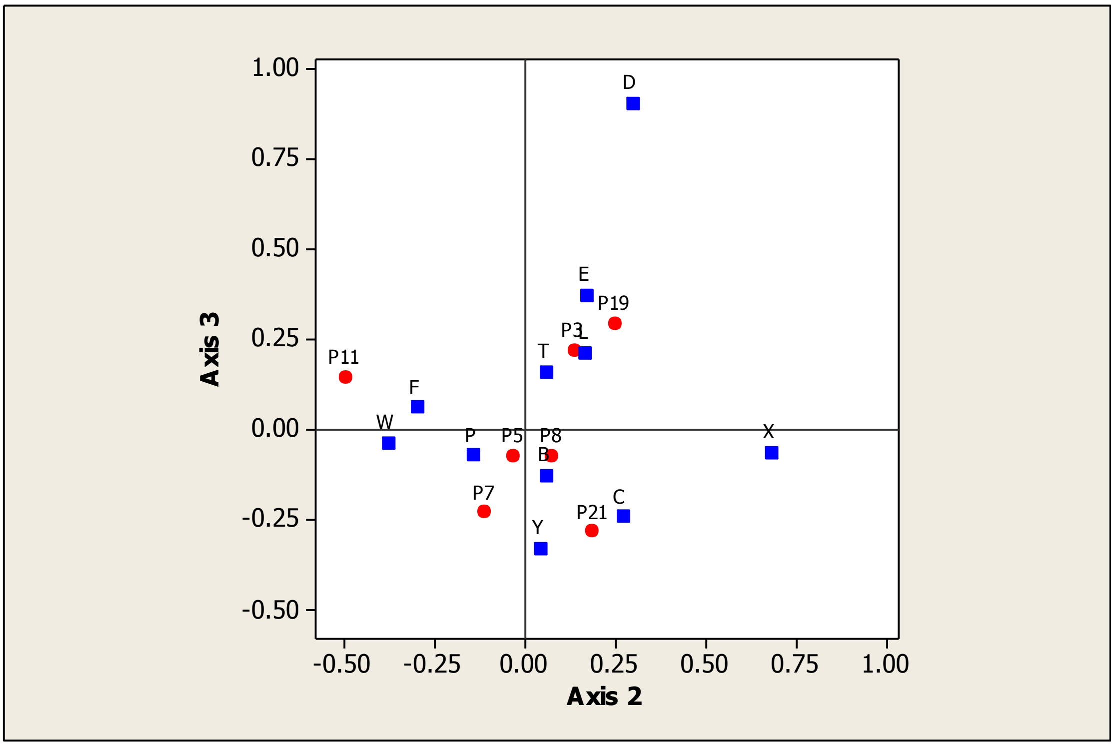


Table 5 Eigen values and cumulative % of the variance in the data accounted for by the ordination axis

Axis	*Eigenvalue/Inertia*	*Cumulative %*
1	*0.1499*	*52.1*
2	*0.0541*	*70.9*
3	*0.0427*	*85.7*
4	*0.0233*	*93.8*
5	*0.0168*	*99.6*
6	*0.0009*	*100*

Table 6 Derived variables giving the position of each activity on the axes and the contribution of behaviours to the axes.

	Axis 1		***Axis 2***		***Axis 3***	
Behaviour	*Variable*	*Contribution*	*Variable*	*Contribution*	*Variable*	*Contribution*
F	*0.400*	*0.149*	*-0.299*	*0.230*	*0.063*	*0.013*
L	*0.280*	*0.027*	*0.164*	*0.026*	*0.214*	*0.056*
E	*-0.283*	*0.067*	*0.168*	*0.065*	*0.375*	*0.413*
W	*0.053*	*0.002*	*-0.379*	*0.348*	*-0.037*	*0.004*
P	*-0.056*	*0.001*	*-0.146*	*0.017*	*-0.070*	*0.005*
C	*0.452*	*0.197*	*0.267*	*0.190*	*-0.240*	*0.195*
D	*1.010*	*0.054*	*0.294*	*0.013*	*0.905*	*0.153*
X	*1.387*	*0.136*	*0.679*	*0.090*	*-0.063*	*0.001*
Y	*-0.167*	*0.002*	*0.042*	*0.000*	*-0.330*	*0.022*
B	*0.363*	*0.363*	*0.057*	*0.018*	*-0.127*	*0.108*
T	*-0.027*	*0.000*	*0.054*	*0.003*	*0.159*	*0.030*

(‘frozen’) as opposed to ‘clawing’. The positioning of P19 on the ordination suggests a less balanced time-budget than other subjects which is countered by time spent feeding on both live *O. smaragdina* (‘Live ants’) and *crematogaster* spp. of ant (‘black ants’). P21 is affiliated most closely with ‘climbing’ suggesting the subject allocates time to this behaviour as opposed to ‘digging’. ‘Clawing’ behaviour is isolated on the right of the ordination and ‘digging’ at the extreme end of Axis 3 (Figure 3b) suggesting no specific affiliation between the behaviours and particular subjects.

Behavioural super category analysis

Subject P11 allocated the greatest amount of active time to feeding, 43.4 ± 6.5 % and P7 the lowest, 21.7 ± 2.7 % (Figure 2). P19 spent the least time in locomotion (13.4 ± 3.5 %) while P21 spent the most (40.7 ± 3.9 %). The lowest percentage of time spent hidden (in ‘bed box’) was recorded for P3 (9.7 ± 3.6 %), the highest for P8 (47.5 ± 4.9 %). Time spent in other behaviour between the subjects ranged from 7.5 ± 2.9 % (P8) to 16.2 ± 4.0 % (P3).

Analysis details significant overall differences between subjects between the amount of time spent in super category behaviours; feeding, locomotion, hidden and other (MANOVA, Pillai trace $F = 4.789$, *d.f.* 18, *d.f.*2. 735, $p = <0.001$). The p-values from post-hoc analysis using Hotelling’s pairwise comparisons are shown in Table 7. Bonferroni uncorrected values were chosen as the corrected test has little power. There were significant differences between P3 and P5 ($p = < 0.001$), P3 and P7 ($p = < 0.001$), P3 and P8 ($p = < 0.001$), P3 and P19 ($p = < 0.001$), P5 and P8 ($p = 0.012$), P5 and P21 ($p = 0.036$), and between P7 and P11 ($p = 0.001$), P7 and P19 ($p = 0.031$) and P7 and P21 ($p = < 0.001$). There were significant differences between P8 and P11 ($p = < 0.001$), P8 and P19 ($p = 0.011$), P8 and P21 ($p = < 0.001$), P11 and P19 ($p = 0.007$) and P19 and P21 ($p = < 0.001$). There weren’t significant differences between other subjects.

Table 7 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	-	-	-	-	-	-	-

ARBs

Figure 1 shows the incidence of clawing by P3, P8 and P21. P5, P7 and P8 displayed another ARB which consisted of pacing certain routes (walking laps) around enclosures. The incidence of clawing was low or marginal as indicated earlier.

Pacing was exhibited predominantly by P5 and was less frequently observed in P7 and P8. Observations of P5 showed that each lap took ~1 min to complete. The number of laps walked varied from 2 to >5. On conclusion of the lap the subject either walked another lap immediately, went to the entrance to the burrow or to the porcelain feeding bowl. When the subject went to the burrow entrance or feeding bowl it was often observed to start a lap again after a brief (<20 s) duration of time spent feeding on frozen *O. smaragdina*, in the bed box or paused.

Enclosure manipulation

P3 was observed clawing in eight focal animal samples, the first on 23 March and the last on 31 March. Time spent in this state as a proportion of 15 min focal animal samples ranged from 1 % (9 s) to 66.5 % (599 s, n = 8). This behaviour was predominantly directed at the bamboo matting administered previously to reduce the then undefined clawing behaviour. After the final sheet of bamboo was removed on 31 March the behaviour was not observed again.

Clawing behaviour was observed in P21 within preliminary observations. It wasn’t observed prior to the date of enclosure manipulation once the study had commenced. It was observed in five focal animal samples between 22 and 26 April and comprised between 2.7 % (25 s) and 47.8 % (431 s, n = 5) of focal animal samples. The behaviour was observed in P21 both before and after enclosure manipulation and was predominantly directed at the ceiling fencing and the top of the door where there were gaps between metal bars.

Activity patterns

Activity patterns for all subjects are presented in Figure 4. Subjects were never sighted as active before 17:00 h. The last scan on any given night where a subject was sighted as active was 04:45 h, the last scan undertaken. The subsequent animal focal sample observed the subject, P8 as active until after 05:00 h. It is not known how long subjects were active once they had left the bed box but focal animal samples detail the range from 4 s to >15 min. Subjects were sighted as active intermittently over a period of 11.5 h between 17:30 h and 05:00 h.

P8 and P21 were the only subjects sighted as active on circuits between 17:00 and 17:45 h and on occasion both subjects appeared to be waiting for food. Where subjects were housed with a conspecific, both subjects were sighted as active most frequently within the same time period (Figure 4). P5 and P7 were sighted as active most frequently between 20:00 and 20:45 h. P11 and P19 were sighted as active most frequently between 19:00 and 19:45 h. P21 was most frequently observed as active between 18:00 and 19:00 h. On this evidence an overall peak activity period between 18:00 and 21:00 h is suggested. Peak activity for all subjects occurred in the first half of the night. In the latter half of the night (23:00-05:00) all subjects were sighted as active on <10 % of circuits.

Environmental variables

Multiple linear regression analysis determined that the environmental variables were not significantly related to any of the behaviours, ‘walking’, ‘climbing’ or ‘clawing’, with the exception of two relationships, ‘climbing’ and temperature and ‘climbing’ and rainfall at 05:00 h. Little variation of the behaviours was explained in the analyses: ‘walking’, S = 0.195, r^2 = 0.7 %, temperature (p = 0.389), rH (p = 0.322), rainfall at 05:00 h (p = 0.607), rainfall at 17:00 h (p = 0.864), ANOVA, F = 0.43, p = 0.784; ‘climbing’, S = 0.338, r^2 = 9.3 %, temperature (p = 0.001), rH (p = 0.080), rainfall at 05:00 h (p = 0.024), rainfall at 17:00 h (p = 0.127), ANOVA, F = 6.11, p = 0.000; ‘clawing’, S = 0.123, r^2 = 1.5 % , temperature (p = 0.568), rH (p = 0.639), rainfall at 05:00 h (p = 0.327), rainfall at 17:00 h (p = 0.429), ANOVA, F = 0.90, p = 0.465.

With the exception of a weak correlation between the proportion of time spent climbing and moon phase, Spearman’s rank analysis determined no correlations between behaviours and moon phase or cloud cover, though little variation was explained: ‘walking’, moon phase (r = 0.115, r^2 = 1.32 %), cloud cover (r = -0.163, r^2 = 2.65 %); ‘climbing’, moon phase (r = 0.350, r^2 = 12.25 %), cloud cover (r = -0.208,

$r^2 = 4.32$ %); ‘clawing’, moon phase ($r = 0.126$, $r^2 = 1.58$ %), cloud cover ($r = 0.001$, $r^2 = < 1$ %).

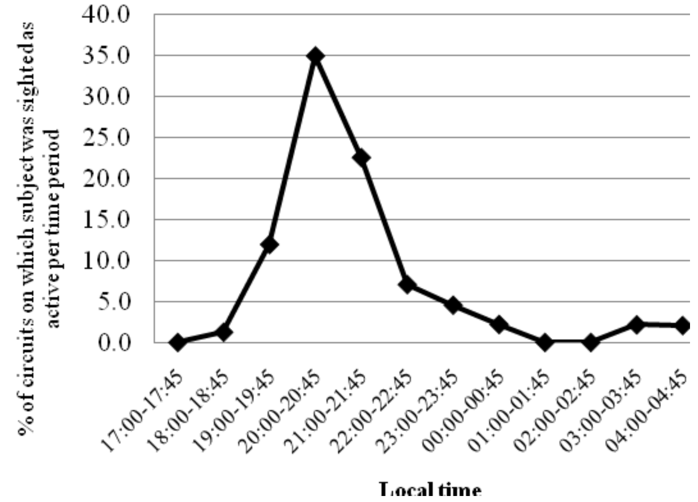
With the exception of three associations, the non-linear regression determined no other significant relationships. The analysis explained little variation. Two significant relationships were evident with ‘climbing’: temperature (cubic, $r^2 = 0.089$, ANOVA, $F = 8.091$, *d.f.* 251, $p = 0.000$) and rH (cubic, $r^2 = 0.012$, ANOVA, $F = 1.03$, *d.f.* 251, $p = 0.379$). There weren’t significant relationships between ‘climbing’ and rainfall; rainfall at 05:00 h (cubic, $r^2 = 0.030$, ANOVA, $F = 2.461$, *d.f.* 241, $p = 0.063$), rainfall at 17:00 h (cubic, $r^2 = 0.039$, ANOVA, $F = 3.387$, *d.f.* 251, $p = 0.019$). No significant non-linear relationships were determined between ‘walking’ and the variables: temperature (cubic, $r^2 = 0.017$, ANOVA, $F = 1.417$, *d.f.* 251, $p = 0.238$), rH (cubic, $r^2 = 0.016$, ANOVA, $F = 1.385$, *d.f.* 251, $p = 0.248$), rainfall at 05:00 h (cubic, $r^2 = 0.015$, ANOVA, $F = 1.186$, *d.f.* 241, $p = 0.316$), rainfall at 17:00 h (cubic, $r^2 = 0.002$, ANOVA, $F = 0.191$, *d.f.* 251, $p = 0.902$). One significant relationship was determined pertaining to ‘clawing’, rainfall at 05:00 h (cubic, $r^2 = 0.103$, ANOVA, $F = 9.080$, *d.f.* 241, $p = 0.000$) but no other variables, temperature (cubic, $r^2 = 0.006$, ANOVA, $F = 0.479$, *d.f.* 251, $p = 0.697$), rH (cubic, $r^2 = 0.018$, ANOVA, $F = 1.486$, *d.f.* 251, $p = 0.219$) and rainfall at 17:00 h (cubic, $r^2 = 0.006$, ANOVA, $F = 0.528$, *d.f.* 251, $p = 0.663$).

Inter-observer reliability

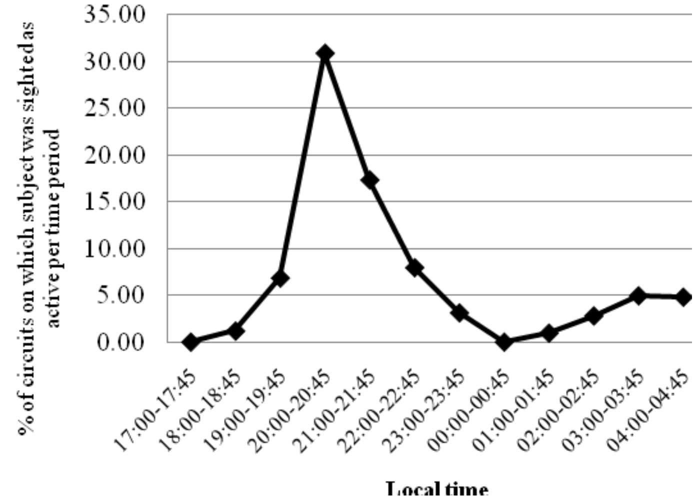
Inter-observer reliability assessments were conducted prior to the investigation on 19, 21 and 22 March. Two assessments were undertaken on the latter date. The resulting Kappa coefficient scores were, $K = 0.90$, 0.74, 0.82 and 0.89 respectively. These scores were considered excellent with observers demonstrating a high level of agreement. Three assessments undertaken throughout the study on 4, 15 and 22 April produced even higher Kappa scores of $K = 0.94$, 0.90 and 0.92 respectively.

Figure 4 - Activity patterns of subjects P3-P21

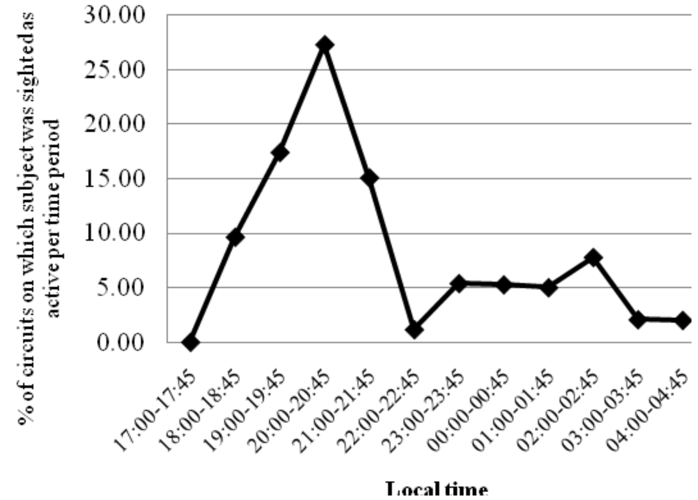
(a) P3 ($n = 1,036$)



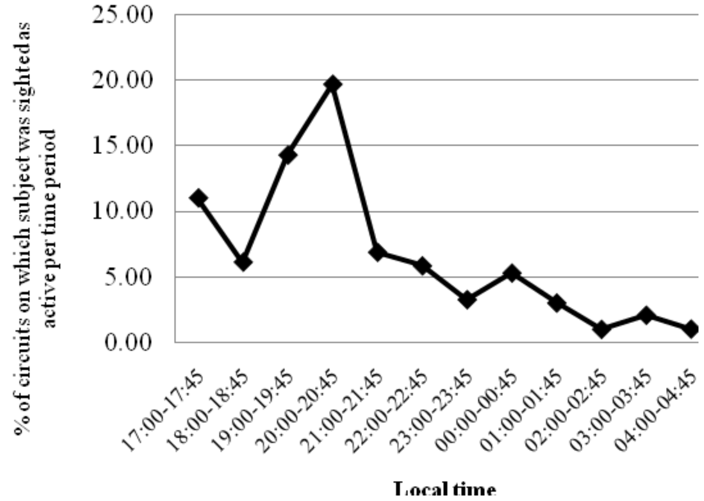
(b) P5 ($n = 1,114$)



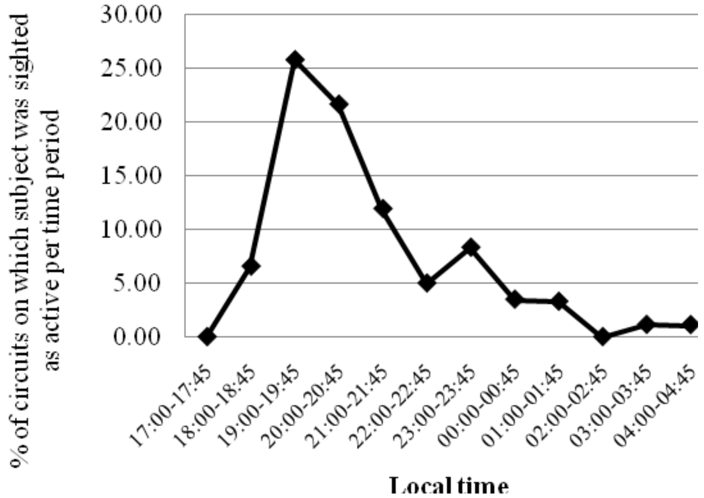
(c) P7 ($n = 1,075$)



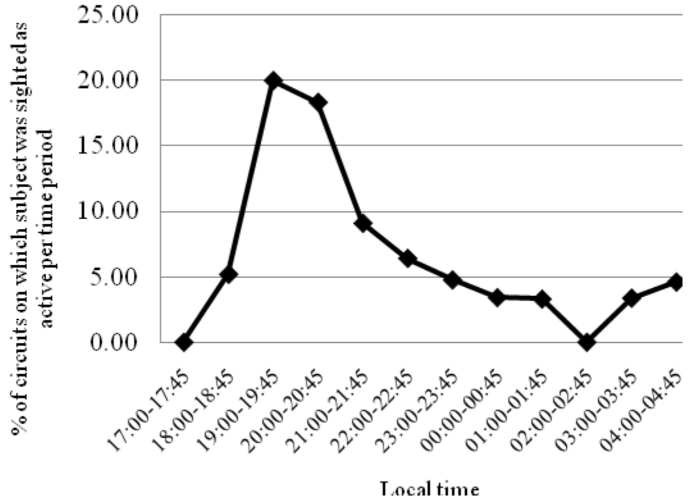
(d) P8 ($n = 1{,}080$)

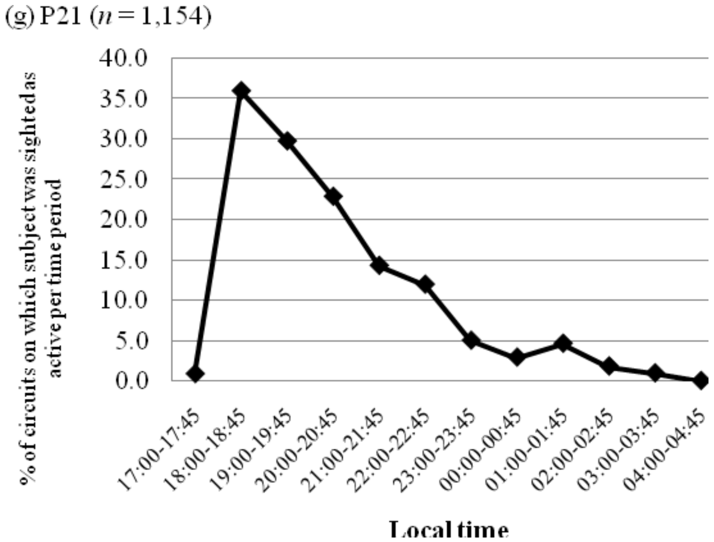


(e) P11 ($n = 974$)



(f) P19 ($n = 971$)





(g) P21 (*n* = 1,154)

% of circuits on which subject was sighted as active per time period
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
17:00-17:45
18:00-18:45
19:00-19:45
20:00-20:45
21:00-21:45
22:00-22:45
23:00-23:45
00:00-00:45
01:00-01:45
02:00-02:45
03:00-03:45
04:00-04:45
Local time

Discussion

There has been extremely limited success of maintaining arboreal pangolins species in captivity (Heath & Vanderlip, 1988) and this is the first study to report on the captive behaviour of *M. javanica*. It should be acknowledged that this study was undertaken on a group of subject's resident at the CPCP which were confiscated from the trade and were not randomly selected. However, it is hoped it can aid the development of the most appropriate captive management and husbandry techniques for *M. javanica*.

Descriptive time-budgets and correspondence analysis showed that there were differences in the active time budgets between subjects. The comparatively high proportion of time spent out of sight by P11 and P19 can be attributed to a burrow being dug and the subjects opting to sleep there as opposed to in the bed box. This was noticed on April 9, the subjects having spent the night of April 8 in the burrow. Subjects continued to use the burrow for the duration of the study and only returned to the bed box on nights of intense rainfall. Due to the burrow entrance being partially covered by vegetation, it was unknown whether subjects were active or had returned to the burrow throughout focal samples after this date. Such behaviour was recorded as out of sight and is attributed to the high degree of time spent in this state by these subjects. The fact that subjects dug burrows is worth noting as it was understood the species used tree hollows as opposed to excavating burrows (IUCN, 2008).

P11 exhibited the greatest amount of active time spent procuring food which could be attributed to returning to condition post parturition (4 months previously) and the fact that some level of maternal care may still have been present. 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). Observations of social interactions between the subjects also support this assumption.

Differences in the time spent procuring different food types in the study could potentially be related to preferences for different prey species between subjects. Although unknown for *M. javanica, M. pentadactyla* preys upon at least nine termite species and six ant species (Wu *et al*, 2005). P19 spent a greater amount of time procuring *Crematogaster* spp. from nests than other subjects suggesting a preference for this species group as opposed to *O. smaragdina*. Research into prey preference is advocated as an area of future research which would be of benefit to institutions maintaining subjects on native ant species.

The active time-budgets of P7 and P8 were dominated by time spent in the bed box and although behaviour once inside is unknown, movement and rustling were heard. In parallel with the behaviour of *M. pentadactyla* as reported by Heath and Vanderlip (1988), *M. javanica* left and returned to the bed box intermittently. Whether subjects were sleeping or resting in the bed box, analogous to sleeping in nest boxes observed in *M. pentadactyla* (Heath & Vanderlip, 1988) is unknown. The behaviour of subjects in bed boxes should be considered in future studies of captive behaviour.

Heath (1987) suggested that female *M. pentadactyla* were more active over a longer period of time than males. This study only observed one adult male (P8) but it spent the greatest amount of active time in the bed box of all subjects. Whether males of either *M. javanica* or *M pentadactyla* are less active than females remains unknown but could be elucidated through further research.

P11 spent the highest proportion of time engaged in social behaviour which is a function of two instances of P11 and P19 wrestling while P11 was the subject of focal sampling. This behaviour involved P11 and P19 rolling on the floor clawing at each other. On one occasion this behaviour lasted for 12 min. Claws making contact with scales were heard suggesting some level of aggression although the underlying cause and function of this behaviour remains unknown. It was presumably a maternal interaction between P11 and its 4 month old offspring and such behaviour warrants future investigation.

The comparatively low amount of time spent walking by P19 can be attributed to time spent being taxied around by P11.

The function of the small percentage of time spent mounted on the back of the conspecific by P5 and P7 is unknown. It is suspected this behaviour is a consequence of both subjects being housed together from a young age and it is assumed would not naturally arise given the solitary nature of *M. javanica* though associations between adults have been reported (Nowak, 1991). Future research investigating the social structure and behaviour of wild populations may elucidate whether this behaviour is a consequence of rearing condition and the captive environment. Yang *et al* (1999) suggest more than one *M. pentadactyla* can be housed together. P5 and P7 were successfully housed together but it must be acknowledged they were reared together. Maintaining more than one *M. javanica* in one enclosure remains problematic as it is suspected close proximity to conspecifics induces stress (Clark, L. pers. comms.).

Behaviour observed but not defined in the ethogram and recorded as ‘other’ includes resting and defecation. This involved subjects lying at the entrance to burrows with their heads, or at least noses sticking out often with their stomachs to the ground. It is suspected this is related to thermoregulation as it occurred towards the latter, hotter part of the study and was observed in P5, P7 and P8. Such behaviour should be considered in future captive research. The arboreal nature of *M. javanica* and observations of P21 resting amongst branches (at 17:00 h) post the investigation suggests that arboreal bed boxes or artificial tree hollows might prove attractive to the animals. It would provide an alternative location for thermoregulation as well as refuge.

There was an overall significant difference between how subjects partitioned their active time between super category behaviours. Post hoc analysis detailed there were not significant differences between specific subjects. Due to the difference in size and quality of the furnishings between enclosures T1-T4 and Q2, it is perhaps surprising that there were no differences between P3 and P21 and P11 and P21 - all three subjects are adult females but P21 was housed in a different type of enclosure. Similarly, a difference between P3 and P11 may have been expected on the premise that P11 is still exhibiting maternal care. The fact there wasn’t a significant difference between P11 and other adult females, even when social and mount behaviours were classed as ‘other’ in the analysis, suggest that the level of maternal care offered at 4 months is minimal.

This study details subjects displayed more than one form of ARB. Clawing is probably a sign of stress and may become prevalent when the animals are close to death (Clark, L. pers. comms.). As such, efforts should be made to reduce the frequency of this behaviour wherever possible. Clawing can also result in self-inflicted wounds and blood was found on the wall of Q2 near the top of the door - evidence perhaps that the behaviour leads to superficial wounds on the face and fore claws.

It was possible to reduce the frequency of clawing by manipulating the enclosure of P3. The removal of bamboo matting resulted in no further observations of P3 clawing. Manipulating the enclosure of P21 did not result in the cessation of clawing behaviour but it should be acknowledged that the manipulation of Q2 was a subtle change to the structural environment, in contrast to that undertaken in T1. Although no further clawing was observed for the remainder of this study by P3, such behaviour could be exhibited again if stress is induced. The causes of stress in captivity are unknown but are possibly related to proximity to conspecifics, nervousness around human presence (Clark, L. pers. comms.), diet (Nguyen Van, T. pers. comms.), enclosure size or other factors. Where *M. javanica* are maintained in captivity, it is recommended captive management should involve close monitoring of subjects in an attempt to mitigate instances of this behaviour.

Pacing behaviour in the form of laps walked around enclosures was observed predominantly in P5. The frequency of this behaviour was not recorded but stereotypic pacing has also been observed in *M. pentadactyla* (Clark, L. pers. comms). This suggests that *Manis* spp. are predisposed to ARBs and stereotypic behaviours in general. Enclosures T1-T4 were furnished with vegetation and a large network of branches that provided a suitable substitute for natural habitat. Effective furnishings provide stimulation and are conducive to the expression of species-typical behaviour (Maple & Perkins, 1996) but P5 still exhibited pacing behaviour which suggests a sub-optimum captive setting. On this evidence it is suggested individual *M. javanica* be housed in the long term in enclosures no smaller than those reported in this study, 29m^2.

On March 23 and 25 P19 was observed escaping from its enclosure through chain link fencing. It is suggested the extra energy expended in such activity may explain suspicions that P19 was underweight for a 4 month old *M. javanica*. This is supported by the fact P19 weighed 0.7 kg shortly before the study commenced but 1 kg afterward. Applying additional fencing to the enclosure resulted in no further observed escapes. In parallel with observations of juvenile *M. pentadactyla* (Heath & Vanderlip, 1988) P19 was observed to exhibit high levels of energy and activity.

Although the study supports the predominantly nocturnal nature of pangolins (Heath 1987) the activity patterns of *M. javanica* like those of *M. pentadactyla* do vary between subjects. Some diurnal activity was observed on more than one occasion in the early evening (~17:30) and this may be in anticipation of being fed which has been observed previously in captive *M. pentadactyla* (Chen *et al*, 2005). This also suggests (perhaps in contrast to the *M. pentadactyla* studied by Heath (1987) and Heath and Vanderlip (1988)) that *M. javanica* may adapt their activity to a captive environment.

A peak activity period between 18:00 and 21:00 h contrasts with a wild subject where peak activity was between 03:00 and 06:00 h (Lim & Ng, 2007). Such activity in captivity could be related to the provision and timing of food offered to subjects. In contrast to Heath (1987) and Heath and Vanderlip (1988) who reported the cessation of *M. pentadactyla* activity by 02:00 h, *M. javanica* subjects were observed as active up to 05:00 h and over a period of 11.5 h. To maintain species-typical activity patterns in captivity, research would need to concentrate on wild subjects, furthering the work of Lim and Ng (2007) to provide a basis for comparison with captive animals.

Multiple linear regression analysis determined that temperature and rainfall at 05:00 h (i.e. rainfall throughout any given night up to 05:00 h) are significantly related to the proportion of time spent ‘climbing’ by subjects. No linear relationships were determined between time spent in the three behaviours and moon phase or cloud cover. Non-linear regression analysis resulted in significant relationships between the amount of time spent ‘climbing’ and temperature and rainfall at 17:00 h. The analysis resulted in a significant relationship between time spent ‘clawing’ and rainfall at 05:00 h (i.e. throughout the night). Despite the determination of such relationships, all results must be treated with caution because so little variation was elucidated in the analysis.

This study was limited with regards to investigating environmental variables because data were collected over a short period of time. It is suggested that future studies look at the variables in relation to behaviour over a longer time period. Any potential relationship between behaviours and moon phase and cloud cover was potentially adversely affected by the lighting of enclosures to allow for observations which should also be addressed where possible in future research.

It is worth noting that three subjects (P3, P11 and P19) did make the transition from sleeping in bed boxes to burrows that had been dug. This occurred in the latter stage of the study as temperature increased and in agreement with Chen *et al* (2005) suggests that soil burrows provide a more optimum environment for thermoregulation.

Conclusions

The aim of this study was to assess the behaviour of captive Sunda pangolins (*M. javanica*) in order to suggest ways of improving captive care and management. Time-budgets constructed detailed differences in how subjects partitioned their active time between behaviours though not necessarily when behavioural super categories were analysed. Activity patterns suggested an overall peak activity period between 18:00 and 21:00 h. Significant relationships determined between specific behaviours and environmental variables should be treated with caution because so little variation was explained in the analysis, the limitations to this aspect of the study were acknowledged.

Differences in time spent feeding on different prey items between subjects advocates research into prey preferences to improve captive husbandry where native ant and termite species are provided. Pertaining to husbandry, leaf litter provides an alternative to sand as a bedding material. Water bowls are a suitable substitute for litter trays as a place to defecate. The use of arboreal bed boxes is advocated in light of observations of subjects resting amongst branches. This could provide a more optimum environment for thermoregulation and refuge given the arboreal nature of the species. Subjects maintained in captivity should be closely monitored for clawing type behaviour which is an indicator of stress. Where appropriate, attempts should be made to mitigate this behaviour. More than one ARB displayed suggests a sub-optimum captive setting and that *M. javanica* may be predisposed to stereotypic behaviours. It is suggested enclosures no smaller than 29m² be used to house individual *M. javanica* in the long term. Although understood to be solitary in nature two female *M. javanica* were housed together successfully. It is acknowledged the subjects had been reared together from a young age; housing more than one individual together remains problematic.

Ethical note

This study was purely observational and involved no manipulation of the subjects or their environments with the exception of the enclosure manipulation discussed. The subjects resided at the CPCP, Vietnam prior to and post the investigation. A qualified veterinarian was resident at the CPCP for the duration of the study. The study was undertaken with the kind permission of Cuc Phuong National Park, Vietnam.

Acknowledgements

I would like to extend my thanks to all those who facilitated and helped in the planning and undertaking of this project. I would like to thank Dr Les May and Dr Martin Jones of Manchester Metropolitan University for their help in planning data collection and statistical analysis and for their editorial input. I would like to thank Dr Jan Chapman of Manchester Metropolitan University for her help in planning and organising the undertaking of data collection. Thank you to Tracy Pinel for her help in statistical procedures. A special thanks to Nguyen Van Thai for his help in organising the study and in undertaking data collection. Thank you to Leanne Clark for her help in facilitating the study. Thank you to Tran Quang Phuong for his help in organising visas and facilitating the study. Thank you to all staff and keepers at the CPCP for their help and support while undertaking the research. Thank you to Do Van Lap, Tran Quang Bich and Cuc Phuong National Park, Vietnam for permitting the undertaking of the research.

References

Allen, G. M. (1938). *The mammals of China and Mongolia*. The American Museum of Natural History, New York.

Bakeman, R. And Gottman, J. M. (1997). *Observing Interaction: An introduction to sequential analysis*, 2nd Edition, Cambridge University Press.

Beltran, J. and Delibes, M. (1994). Environmental determinants of circadian activity of free-ranging Iberian lynxes. *J. Mammal*. 75, 382-393.

Benzecri, J. P. (1973). Analyse des données. 2 vols. Dunod, Paris cited in Boy, V. and Duncan, P. (1971). Time-budgets of Camargue Horses, I. Developmental changes in the time-budgets of foals. *Behaviour*, 71, 3-4.

Bernstein, M. (1976) cited in Boy, V. and Duncan, P. (1971) Time-budgets of Camargue Horses, I. Development changes in the time-budgets of foals. *Behaviour*, 71, 3-4.

Birdlife (2008). Accessed 11/7/08. http://birdlifeindochina.org/source_book/source_book/frs_rrd_fr2.html

Boonsong Lekagul and McNeely, J. A. (1977). *Mammals of Thailand*, Association for the Conservation of Wildlife, Bangkok.

Boy, V. and Duncan, P. (1971). Time-budgets of Camargue Horses, I. Development changes in the time-budgets of foals. *Behaviour*, 71, 3-4.

Brautigam, A., Howes, J., Humphrey, S. T. and Hutton, J. (1994). Recent information on the status and utilization of African pangolin. *TRAFFIC Bulletin* No. 15, cited in Wu, S., Liu, N. F., Ma, G. Z., Xu, Z. R. and Chen, H. (2003). Habitat Selection by Chinese Pangolin (*Manis pentadactyla*) in Winter in Dawuling Natural Reserve.

Chen, SM., Hsi, CC., Chen, YM. and Chang, MH. (2005). Activity pattern of Formosan pangolin (*Manis pentadactyla pentadactyla*) in captivity. Taipei Zoo, Taipei, R.O.C.

CITES (2000). Proposal 11.13. *Manis crassicaudata*, *Manis pentadactyla*, *Manis javanica*, Transfer from Appendix II to Appendix I (India, Nepal, Sri Lanka, United States) CITES.

CITES (2008). Accessed 4/10/08. http://www.cites.org/eng/app/appendices.shtml

Crandall, L. S. (1964). *The management of wild mammals in captivity*. Chicago and London: University of Chicago Press.

Davies, G. and Payne, J. (1982). *A faunal survey of Sabah*. WWF Malaysia, Kuala Lunpur, cited in CITES (2000). Proposal 11.13. *Manis crassicaudata, Manis* *pentadactyla, Manis javanica,* Transfer from Appendix II to Appendix I (India, Nepal, Sri Lanka, United States) CITES.

Dixon, D. R., Dixon, L. R. J., Bishop, J. D. and Pettifor, R. A. (2006) Lunar related reproductive behaviour in the badger (*Meles meles*) *Acta Ethologica*.

Eisenberg, J. F. (1981). *The mammalian radiations.* Chicago, The University of Chicago Press cited in Heath, M. E. and Vanderlip, S. L. (1988). Biology, Husbandry and Veterinary Care of Captive Chinese Pangolins (*Manis pentadactyla*) *Zoo Biology* 7: 293-312.

Elangovan, V. and Marimuthu, G. (2001). Effect of moonlight on the foraging behaviour of a megachiropteran bat *Cynopterus sphinx. Journal of Zoological Society of London,* 253: 347-350.

Ellis, R. (2005). *Tiger Bone and Rhino Horn: The destruction of wildlife for Traditional Chinese Medicine,* Island Press.

ENV (2007). Education for Nature Vietnam, Wildlife Crime Bulletin, Feature ‘The Pangolin Trade’ January 2007.

Finley, R. B. Jr. (1959). Observation of nocturnal animals by red light. *Journal of Mammalogy,* Vol. 40, No. 4: 591-594.

Fisher, R. A. (1940). The precision of discriminant functions. *Ann. Eugen. Lond.* 10: 422-429 cited in Boy, V. and Duncan, P. (1971). Time-budgets of Camargue Horses, I. Development changes in the time-budgets of foals. *Behaviour,* 71, 3-4.

Foenander, E. C. (1953). The elephant’s terror. *Malayan Nature Journal* 8:23-24 cited in CITES (2000). Proposal 11.13. *Manis crassicaudata, Manis pentadactyla, Manis javanica,* Transfer from Appendix II to Appendix I (India, Nepal, Sri Lanka, United States) CITES.

Forthman, D. L. and Bakeman, R. (1992). Environmental and Social Influences on Enclosure Use and Activity Patterns of Captive Sloth Bears (*Ursus ursinus*), *Zoo Biology* 11: 405-415.

Francis, C. M. (2007). *A photographic guide to Mammals of South-East Asia.* New Holland Publishers (UK) Ltd.

Garner, J. (2008). Perseveration and stereotypy: systems-level insights from clinical psychology, cited in Mason, G., Rushen, J. (Eds.), *Stereotypic Behaviour in Captive Animals: Fundamentals and Applications for Welfare*, 2nd ed. CAB International, Wallingford.

Gaubert, P. and Antunes, A. (2005). Assessing the taxonomic status of the Palawan pangolin *Manis Culionensis* (Pholidota) using discrete morphological chartacters, *Journal of Mammalogy*, 86 (60): 1068-1074.

Grubb, P. and Jewell, P. A. (1974). Movement, daily activity and home range of Soay sheep cited in Jewell, P. A., Milner, C. and Morton-Boyd, J. (Eds). *Island survivors: The ecology of the Soay sheep of St. Kilda*, Athlone Press, Univ. London.

Heath, M. E., (1987). Twenty-four-hour variations in Activity, Core temperature, Metabolic Rate, and Respiratory Quotient in Captive Chinese Pangolins. *Zoo Biology* 6: 1-10.

Heath, M. E. and Vanderlip, S. L. (1988). Biology, Husbandry and Veterinary Care of Captive Chinese Pangolins (*Manis pentadactyla*) *Zoo Biology* **7**:293-312.

Hill, M. O. (1974). Correspondence analysis: a neglected multivariate method. *Appl. Stat*. 23: 340-354 cited in Boy, V. and Duncan, P. (1971). Time-budgets of Camargue Horses, I. Development changes in the time-budgets of foals. *Behaviour*, 71, 3-4.

Hoyt, R. A. (1987) Pangolins: past, present and future. *AAZPA a. Conf. Proc.* 1987: 107-134 cited in Wilson, A. E. (1994). Husbandry of pangolins. *International Zoo Yearbook* 33: 248-251, Zoological Society of London.

ISIS, (2008) International Species Information System. Available website: www.isis.org. Accessed 27/10/08

IUCN 2008. *2008 IUCN Red List of Threatened Species*. <www.iucnredlist.org>. Downloaded on 27 October 2008.

Jacobsen, N.H.G., Newbery, R.E., De Wet, M.J., Viljoen, P.C., and Pietersen, E. (1991). A contribution of the ecology of the steppe pangolin *Manis temminckii* in the Transvaal. *Z. Saugetierk*, 56, 94-100.

Jones, M. L. (1977). Longevity of mammals in captivity. *International Zoo News* 159: 16-19.

Kendall, M. G. and Stuart, A. (1968). *The advanced theory of statistics*, Vol. 3. Butler and Tanner, London, 2e ed cited in Boy, V. and Duncan, P. (1971). Time-budgets of Camargue Horses, I. Development changes in the time-budgets of foals. *Behaviour*, 71, 3-4.

Kingdon, J. (1971). *East African Mammals: An atlas of evolution*: I. London & New York: Academic press cited in Swart, J. M., Richardson, P. R. K. and Ferguson, J. W. H. (1999). Ecological factors affecting the behaviour of pangolins (*Manis temminckii*). *Journal of the Zoological Society of London* 247: 281-292.

Lebart, L. and Fenlon, J-P. (1971). Statistique et informatique appliqués. Dunod, Paris cited in Boy, V. and Duncan, P. (1971). Time-budgets of Camargue Horses, I. Development changes in the time-budgets of foals. *Behaviour*, 71, 3-4.

Lekagul, B. and McNeely, J. A. (1988). *Mammals of Thailand*, Association for the Conservation of Wildlife, Bangkok.

Lim, N. T. L. and Ng, P. K. L. (2007). Home range, activity cycle and natal den usage of female Sunda pangolin *Manis javanica* (Mammalia: Pholidota) in Singapore, *Endangered Species Research*, Vol. 3.

Luo, S-J., Cai, Q-X., David, V. A., Zhang, L., Martelli, P., Lim, N. T-L., Ferrand, N., Chin, S-C., Gaubert, P., Ramos, M, J., O'Brien, S. J., Antunes, A. and Johnson, W. E. (2007) Isolation and characterisation of micro satellite markers in pangolins (Mammalia, Pholidota, *Manis* spp.) *Molecular Ecology Notes* 7: 269-272.

MacDonald, D., W. (2006). *The Encyclopedia of Mammals*, 2nd Edition, Oxford University Press.

Maple, T. L. and Perkins, L. A. (1996). Enclosure Furnishings and Structural Environmental Enrichment, Chapter 21, *Wild Mammals in captivity: principles and techniques*, University of Chicago Press.

Martin, P. and Bateson, P. (2007). *Measuring Behaviour: An Introductory Guide*, Cambridge University Press.

Mason, G. J. (1991). Stereotypies: A critical review. *Animal Behaviour* 41: 1015-1037.

Mason, G., Clubb, R., Latham, N. and Vickery, S. (2007). Why and how should we use environmental enrichment to tackle stereotypic behaviour? *Applied Animal Behaviour Science* 102: 163-188.

Medway, Lord (1969). *The Wild Mammals of Malaya and Singapore.* Oxford University Press, Oxford cited in CITES (2000). Proposal 11.13. *Manis crassicaudata, Manis pentadactyla, Manis javanica*, Transfer from Appendix II to Appendix I (India, Nepal, Sri Lanka, United States), CITES.

Medway, Lord (1977). Mammals of Borneo. *Monographs of the Malaysian Branch of the Royal Asiatic Society* 95(3): 495-497 cited in CITES (2000). Proposal 11.13. *Manis crassicaudata, Manis pentadactyla, Manis javanica*, Transfer from Appendix II to Appendix I (India, Nepal, Sri Lanka, United States), CITES.

Misra, M. and Hanfee, F. (2000). Pangolin distribution and trade in East and Northeast India. *TRAFFIC Dispatches* No.14.

Newton, P., Nguyen Van, T., Roberton, S. and Bell, D. (2008). Pangolins in Preil: Using local hunters' knowledge to conserve elusive species in Vietnam. *Endangered Species Research*, Vol. 6, 41-53.

Nowak, R. M. (1991). *Walker's Mammals of the World* 5th ed. The John Hopkins University Press. Baltimore and London.

Nowak, R. M. (1999) *Walker's Mammals of the World.* Baltimore: The John Hopkins University Press.

Ödberg, F. O. (1978). Abnormal behaviours (stereotypies). In: Proceedings of the 1st World Congress on Ethology Applied to Zootechnics, Madrid, Spain, 475-480.

Payne, J., Francis, C. M., Phillips, K. (1985). *A field guide to the mammals of Borneo.* The Sabah Society with the World Wildlife Fund Malaysia.

Payne, J. and Francis, C. M. (1998). *A field guide to the mammals of Borneo*, The Sabah Society , Kota Kinabalu cited in Lim, N. T. L and Ng, P. K. L (2007) Home range, activity cycle and natal den usage of female Sunda pangolin *Manis javanica* (Mammalia: Pholidota) in Singapore, *Endangered Species Research*, Vol. 3.

Pocock, R. I. (1924). The external characters of the pangolins (*Manidae*). *Proceedings of the Zoological Society of London*, 707-723 cited in Gaubert, P. and Antunes, A. (2005). Assessing the taxonomic status of the Palawan pangolin *Manis Culionensis* (Pholidota) using discrete morphological chartacters, *Journal of Mammalogy*, 86 (60): 1068-1074.

Richer, R. A., Coulson, I. M., and Heath, M. E. (1997). Foraging behaviour and ecology of the cape pangolin (*Manis temminckii*) in north-western Zimbabwe. *African Journal of Ecology*, Vol. 35: 361-369.

Roberts, T. J. (1977). *The mammals of Pakistan.* Benn, London cited in CITES (2000). Proposal 11.13. *Manis crassicaudata, Manis pentadactyla, Manis javanica*, Transfer from Appendix II to Appendix I (India, Nepal, Sri Lanka, United States), CITES.

Rose, K. D. (2001). Edentata and Pholidota. *Encyclopedia of Life Sciences*, 1-7.

Samson, C. and Raymond, M. (1995). Daily activity pattern and time-budget of stoats (*Mustela erminea*) during summer in Southern Québec. *Mammalia* 59: 501-510.

Schlitter, D. A. (2005). Order Pholidota., *Mammal Species of the World*: A taxonomic and Geographic reference, Wilson, D. E. and Reeder, D. M., John Hopkins University Press, Baltimore, MD cited in IUCN 2008. *2008 IUCN Red List of Threatened Species.* <www.iucnredlist.org>. Downloaded on 27 October 2008.

Smithers, R. H. N. (1983). *The mammals of the Southern African subregion*. Pretoria: University of Pretoria cited in Swart, J. M., Richardson, P. R. K. and Ferguson, J. W. H. (1999). Ecological factors affecting the behaviour of pangolins (*Manis temminckii*). *Journal of the Zoological Society of London* 247: 281-292.

Sodiende, O. A. and Adedipe, S. R. (1995). Pangolin in South-west Nigeria-Current status and prognosis. *Oryx* 28: 4348 cited in Wu, S. B., Liu, N. F., Ma, G. Z., Xu, Z. R. and Chen, H. (2003). Habitat Selection by Chinese Pangolin (*Manis pentadactyla*) in Winter in Dawuling Natural Reserve.

Swart, J. M., Richardson, P. R. K. and Ferguson, J. W. H. (1999). Ecological factors affecting the behaviour of pangolins (*Manis temminckii*). *Journal of the Zoological Society of London* 247: 281-292.

Sweeney, R. C. H. (1956). Some notes on the feeding habits of the ground pangolin, *Smutsia temminckii* (Smuts). *Ann Mag. Nat. Hist. 12th ser.* 9: 893-896 cited in Swart, J. M., Richardson, P. R. K. and Ferguson, J. W. H. (1999). Ecological factors affecting the behaviour of pangolins (*Manis temminckii*). *Journal of the Zoological Society of London* 247: 281-292.

Tenaza, R. R. and Schultz, T. A. (1977). Natural and synthetic diets for Pholidota, pp. 549-553 in *CRC HANDBOOK SERIES IN NUTRITION AND FOOD*. M. Recheigl, Jr., ed. Cleveland, CRC Press cited in Heath, M. E. (1987). Twenty-four-hour variations in Activity, Core temperature, Metabolic Rate, and Respiratory Quotient in Captive Chinese Pangolins. *Zoo Biology* 6: 1-10.

TRAFFIC Southeast Asia (2004). Armoured but endangered, *Asian Geographic,* 4, 64-71.

Weller, S. H. And Bennett, C. L. (2001). Twenty-four hour activity budgets and patterns of behaviour in captive ocelots (*Leopardus pardalis*). *Applied Animal Behaviour Science* 71: 67-79.

Wilson, A. E. (1994). Husbandry of pangolins. *International Zoo Yearbook* 33: 248-251, Zoological Society of London.

World Bank. (2005). Vietnam Environment Monitor 2005: Biodiversity

World Bank. (2005a). ‘Going, going, gone... The Illegal Trade in Wildlife in East and Southeast Asia’. Environment and Social Development East Asia and Pacific Region Discussion paper.

Wu, S. B. (1998). Classification and distribution of pangolins and their protection status in the world. Pp. 130-138 cited in Wu, S. B., Liu, N. F., Ma, G. Z., Xu, Z. R. and Chen, H. (2003). Habitat Selection by Chinese Pangolin (*Manis pentadactyla*) in Winter in Dawuling Natural Reserve.

Wu, S. B., Ma, G. Z., Tang, M., Chen, H. and Liu, N. F. (2002). The status and conservation strategy of pangolin resource in China. *Journal of Natural Resource* 17, 174-180 (In Chinese with English abstract) cited in Wu, S. B., Liu, N. F., Ma, G. Z., Xu, Z. R. and Chen, H. (2003). Habitat Selection by Chinese Pangolin (*Manis pentadactyla*) in Winter in Dawuling Natural Reserve.

Wu, S., Liu, N. and Li, Y. (2005). Preliminary observation on food habit and foraging behaviour in Chinese pangolin (*Manis pentadactyla*). *Chinese Journal of Applied and Environmental Biology*, No. 3.

Yang, CW., Chou, CS., Chao, MS. (1999). The feeding of the Chinese pangolin (*Manis pentadactyla pentadactyla*) at Taipei Zoo. AZA Annual Proceedings. P.501-507.

Yang, CW., Chen, S., Chang, C-Y., Lin, M., Block, E., Lorentsen, R., Chin, J. S. C., and Dierenfeld, E. S. (2007).History and Dietary Husbandry of Pangolins in captivity, *Zoo Biology* 0:1-8.

Zar, J. H. (1999). *Biostatistical Analysis,* fourth edition, Prentice Hall, Upper Saddler River, New Jersey.