JZAR JOURNAL OF ZOO AND AQUARIUM RESEARCH
www.jzar.org

JZAR Research article

OPEN ACCESS

Research article

Survey of feeding practices, body condition and faeces consistency in captive ant-eating mammals in the UK

Amelia Clark[1,2*], Ayona Silva-Fletcher[3], Mark Fox[4], Michael Kreuzer[5] and Marcus Clauss[6]

[1]*Zoological Society of London, London, United Kingdom*
[2]*The Royal Veterinary College, London, United Kingdom*
[3]*Department of Clinical Sciences and Services, The Royal Veterinary College, Hertfordshire, United Kingdom*
[4]*Department of Pathology and Pathogen Biology, The Royal Veterinary College, London, United Kingdom*
[5]*ETH Zurich, Institute of Agricultural Sciences, Zurich, Switzerland*
[6]*Clinic for Zoo Animals, Exotic Pets and Wildlife, Vetsuisse Faculty, University of Zurich, Switzerland*
**Correspondence: Amelia Clark, 21 W. Cedar Street Unit 3, Boston, Massachusetts, 02108, USA; AClark4@rvc.ac.uk*

Keywords:
aardvark, armadillo, body condition score, diet survey, faecal score, giant anteater

Article history:
Received: 17 February 2016
Accepted: 4 October 2016
Published online: 3 November 2016

Abstract
A survey was conducted investigating the feeding practices, body condition, and faecal consistency of 26 giant anteaters (*Myrmecophaga tridactyla*), 13 aardvarks (*Orycteropus afer*), and 31 armadillos (Dasypodidae spp.) from 20 zoological collections in the UK. For the latter two, scores for body condition (BCS, from 1 – emaciated – to 5 – grossly obese) and faeces (Faecal Score (FS) from 1 – solid – to 5 – diarrhoea-like) were applied. The majority of the UK collections offered a 'complete' feed for anteaters and aardvarks as opposed to the traditional 'gruel' diet. Armadillos were fed mixed diets of fruits, vegetables, eggs, dog or cat food, and various other items. Grossly obese individuals (BCS >4) were only observed in two armadillo species. The average body mass recorded for giant anteaters was above values reported for wild animals, but this was not the case in aardvarks. Anteaters received on average 75% of the amount of dry matter offered to aardvarks, although their basal metabolism is only 60% that of aardvarks; hence, anteaters might have been offered more food than required. The FS for anteaters were higher than for aardvarks or armadillos. Dietary ash, acid detergent fibre and acid insoluble ash (AIA) levels did not correlate with either FS or faecal dry matter (DM). However, there were negative correlations between faecal ash and AIA content with faecal DM and FS, suggesting that measures increasing AIA intake above that achieved by current diets might beneficially influence FS. Only one anteater had a patent parasite infection; this animal had an FS of 5. Results of this survey will encourage careful monitoring of body mass and diet for giant anteaters and armadillos to avoid obesity. Further studies are needed to investigate the impact of higher levels of indigestible material in anteater diets on faecal consistency, growth, and body condition.

Introduction

Myrmecophagous (ant- and termite-eating) mammals occupy a highly specialised dietary niche with a feeding ecology that is difficult to replicate in captivity. They have a varying range of specialised anatomical adaptations for seizing and ingesting insects, such as a reduction in teeth, pointed snouts, large salivary glands, and anterior extremities designed for digging (Reiss 2001; Taylor et al. 2002; Camilo-Alves and Mourão 2006; Da Silveira Anacleto 2007). Free-ranging myrmecophages have been identified as being either opportunistic (e.g. armadillos) or obligatory (e.g. anteaters and aardvarks) feeders of ants or termites (Redford 1986, 1987a; Morford and Meyers 2003a; Valdes and Brenes Soto 2012; Delsuc et al. 2014). Ants and termites are particularly suitable food sources because their colonial habitats make them available at focal high densities (Redford 1987b).

The nocturnal and solitary ecology of most myrmecophages creates a challenge for observing and understanding their diets and behaviours in the wild (Taylor et al. 2002; Valdes and Brenes Soto 2012). Although the food habits of armadillos (Dasypodidae) have been accurately documented as a result of extensive examination of both stomach and faecal contents, there is little information available on the nutritional requirements of giant anteaters (*Myrmecophaga tridactyla*) and aardvarks (*Orycteropus afer*) (Redford 1986). This has made the development of an adequate diet difficult in captivity, especially while trying to provide behavioural enrichment that satisfies their fossorial needs (Valdes and Soto 2012). In addition, giant anteaters have a lower basal metabolic requirement when compared to the mammalian average (McNab 1984) for which their diets have historically been designed, possibly making them susceptible to overfeeding and obesity (Stahl et al. 2012). Though there have been some systematic evaluations of myrmecophage diets, poor knowledge of their nutritional needs has led to a historically inadequate nutrition profile as well as numerous nutrition-related health problems such as rear limb paresis (possibly related to vitamin A toxicosis or excessive vitamin D and/or calcium), other lesions associated with high levels of vitamin A, vitamin K deficiency, liquid faeces/diarrhoea, constipation, low blood and plasma taurine concentrations, tongue tip constriction, gastrointestinal tract obstruction, anorexia, obesity, or diabetes (Oyarzun et al. 1996; Steinmetz et al. 2007; Valdes and Brenes Soto 2012; Wyss et al. 2013; Gull et al. 2015).

The design of an appropriate, simple anteater diet that contains a small enough particle size to be easily consumed while also minimising the number of nutrition-related issues has been discussed repeatedly (Meritt 1976, 1977; Shaw et al. 1987; Edwards and Lewandowski 1996; Gull et al. 2012, 2015; Stahl et al. 2012; Valdes and Brenes Soto 2012; Wyss et al. 2013). There are multiple insectivore diets used in captivity that can vary between collections: the traditional gruel-type diet has been used in different combinations and is composed of a mixture of raw meat, dog or cat pellets, low-fat curd cheese, cereal, honey, fruits, boiled egg, and mineral–vitamin supplements (Steinmetz et al. 2007). A lack of fibre and the aim for a more simple diet led to addition of leaf-eater pellets to dry cat or dog food (Edwards and Lewandowski 1996). Additionally, shrimp meal, peat, and chitin have been added to diets in order to improve faecal consistency and provide more indigestible material (Steinmetz et al. 2007). More recently, complete extruded insectivore diets (i.e. Insectivore Diet 5MK8®, Mazuri, Purina Mills, St. Louis, Mo, USA; Termant, Mazuri Zoo Foods, Witham, Essex, UK; Insectivore, Kliba Nafag, Provimi Kliba AG, Kaiseraugst, Switzerland) based on a combination of animal and plant ingredients have become available, providing a more 'complete' diet and involving less preparation time for keepers (Morford and Meyers 2003a; Gull et al. 2015). Zoo collections across the United States began adding leaf-eater pellets and minimising/removing milk products and grains once it was determined that the high levels of grain and lactose and low levels of fibre (specifically, acid detergent fibre, ADF) in the gruel diet were thought to have led to soft faeces (Edwards and Lewandowski 1996; Morford and Meyers 2003a; Valdes and Brenes Soto 2012; Gull et al. 2015). Even with the addition of the leaf-eater pellet and insectivore diet, soft faeces are still a common issue in myrmecophages, especially in the giant anteater (pers. obs; Gull et al. 2015).

The challenge associated with successfully replicating the natural diet of myrmecophages in captivity has implications for their health and welfare. The present study aims to investigate the feeding practices, status of body mass, body conditions and faecal consistencies in captive myrmecophages throughout the United Kingdom (UK), while testing the following hypotheses: (i) There is a direct correlation between the body mass of each adult individual within a species and their body condition score (BCS). Individuals with a higher body mass will have a higher BCS (i.e. be more overweight/obese). (ii) There is a positive correlation between the amount of daily diet fed and BCS. (iii) Drier faeces will contain more total ash and more acid insoluble ash (AIA); therefore, dry matter, total ash and AIA concentrations will be inversely related to faecal score (FS), with 'better' faeces being drier and having more ash. (iv) Faecal AIA concentrations are related to dietary AIA concentrations. Firmer stool/drier faeces (better FS) will be associated with diets containing higher levels of acid detergent fibre (ADF) and acid insoluble ash (AIA); and (v) Individuals with positive parasitological findings will have soft faeces.

Methods

Zoological collection participation

Endorsement from the British and Irish Association of Zoos and Aquariums (BIAZA) assisted in the approval and participation of 20 (out of 26 contacted) collections throughout the UK. Due to low sample size, the aardwolf (*Proteles cristata)* and the southern tamandua (*Tamandua tetradactyla*) were not included in the study.

Animals

From 20 collections in the UK five myrmecophagous species (70 individuals) were surveyed. In detail, 26 giant anteater (*Myrmecophaga tridactyla*), 13 aardvarks (*Orycteropus afer*), 10 southern three-banded armadillo (*Tolypeutes matacus*), 11 larger hairy armadillo (*Chaetophractus villosus*), and nine six-banded/yellow armadillo (*Euphractus sexcinctus*) were subjected to the observational and descriptive study between May and June 2015. The following items were collected for each individual from 18 collections: detailed diet sheet, 500 g daily diet sample, faecal sample, body mass, photograph of faeces, and photograph of individual. Faecal samples and photographic evidence were obtained from the remaining two collections via e-mail and post.

Table 1. Body condition score (BCS) applied to captive giant anteaters (*Myrmecophaga tridactyla*) and aardvarks (*Orycteropus afer*).

BCS	General	Neck/shoulder	Hip/tailhead*
1	Bony, skeletal	Emaciated, bone structure of scapula easily noticeable; no folds visible on neck	Prominent tailhead, hip, and pelvic bones
2	Thin	Thin neck and shoulder	Flattened tailhead, hip, and pelvic bones
2.5	Slightly underweight	Normal size neck, more visible shoulders	Flatter tailhead, more visible hips and pelvic bones
3	Moderate/Fit	Moderate size neck, flattened shoulders	Moderate fat around tailhead, flattened pelvic and hip bones
3.5	Overweight	Thicker neck with minor and rounded shoulder	More apparent fat around tailhead, slightly rounded pelvic and hip bones
4	Moderately obese	Thick neck, visible folds rounded shoulders	Fat around tailhead, rounded hips
5	Grossly obese	Thick neck with visible folds; bone structure of shoulders not visible	Excessive fat around tailhead, hips and pelvic bones very rounded

*Tailhead was only scored for aardvarks.

Table 2. Body condition scoring (BCS) applied to captive armadillos (Dasypodidae spp.).

BCS	General	Body shell/hips/thighs
1	Bony, skeletal	Defined jaw, no fat on underside of shell, bony
2	Thin	No visibility of fat on underside of shell
3	Moderate/fit	Little to no visibility of fat on underside of shell. From lateral view, shell lays flat against the body
4	Moderately obese	Fat around hips and thighs clearly visible. Slight upward push of shell due to presence of fat.
5	Grossly obese	Excessive fat around hips and thighs. Shell above tail visibly pushed upwards due to presence of fat. Fat folds present on underside

Table 3. Faecal consistency score (FS) applied to captive giant anteaters (*Myrmecophaga tridactyla*), aardvarks (*Orycteropus afer*), and armadillo (Dasypodidae spp).

FS	Description
1	Hard and extremely dry – crumbles when pressure applied
1.5	Hard and dry with a distinct shape
2	Well formed without leaving a mark when touched
2.5	Well formed with a moist surface and a mark left when touched
3	Moist and beginning to lose form. Definite mark when picked up
3.5	Very moist with less of a definite form. No longer broken into distinct pieces
4	Most form is lost; poor consistency; difficult to pick up
4.5	Diarrhea with minor areas of solid consistency/shape
5	Watery diarrhoea. No areas of consistency or shape.

Where available, body masses for individuals were collected using the most recently recorded values provided by each collection. All group-housed individuals were fed the same diet, whereas individuals of the same species kept separately within one facility were sometimes fed different diets.

Diet and faeces collection

Keepers and research coordinators were contacted prior to arrival at each collection to organise sample collection. For all individuals, enclosures were left uncleaned from the day prior until after collection was complete. When possible, indoor/outdoor pools in the giant anteater and aardvark enclosures were drained to prevent defaecation in water. Faecal samples were photographed as found in the enclosure, and cleaned of adhering soil, bedding or debris as much as possible. A subsample of approximately 5 g was taken for parasitological screening, and the remainder was weighed and placed in an aluminium foil food storage container. A detailed diet sheet was obtained from each collection and a

Figure 1. Examples of body condition scores (BCS) in captive giant anteaters (*Myrmecophaga tridactyla*) (for a description of the BCS see Table 1) (Photos: A. Clark).

Figure 2. Examples of body condition scores (BCS) in captive aardvarks (*Orycteropus afer)* (for a description of the BCS see Table 1). (Photos: A. Clark).

minimum 500 g sample of the individual's daily diet was collected, weighed, and placed in an aluminium foil food storage container. Occasionally-fed live feed and whole prey items (i.e. mice and chicks) were not included in the dietary analysis. Both faecal and diet samples were transported to the Royal Veterinary College (London, UK) in a cooler box within one day and stored at -20°C until analysed. The subsample for parasitological screening was stored in a refrigerator at the Royal Veterinary College (London, UK) at -4°C until analysed at the Royal Veterinary College laboratories. The amount of faecal samples available from armadillos was too low for all parasitological and some nutrient analyses.

Body condition score and faecal score

Photographs of individuals were taken and a body condition score (BCS) was assigned consistently by one investigator (AC). The BCS for the giant anteater and aardvark was based on the appearance and prominence of the scapula, hips, and neck (Table 1, Fig. 1), as well as the tail head (aardvark only) (Table 1, Fig. 2). For armadillos,

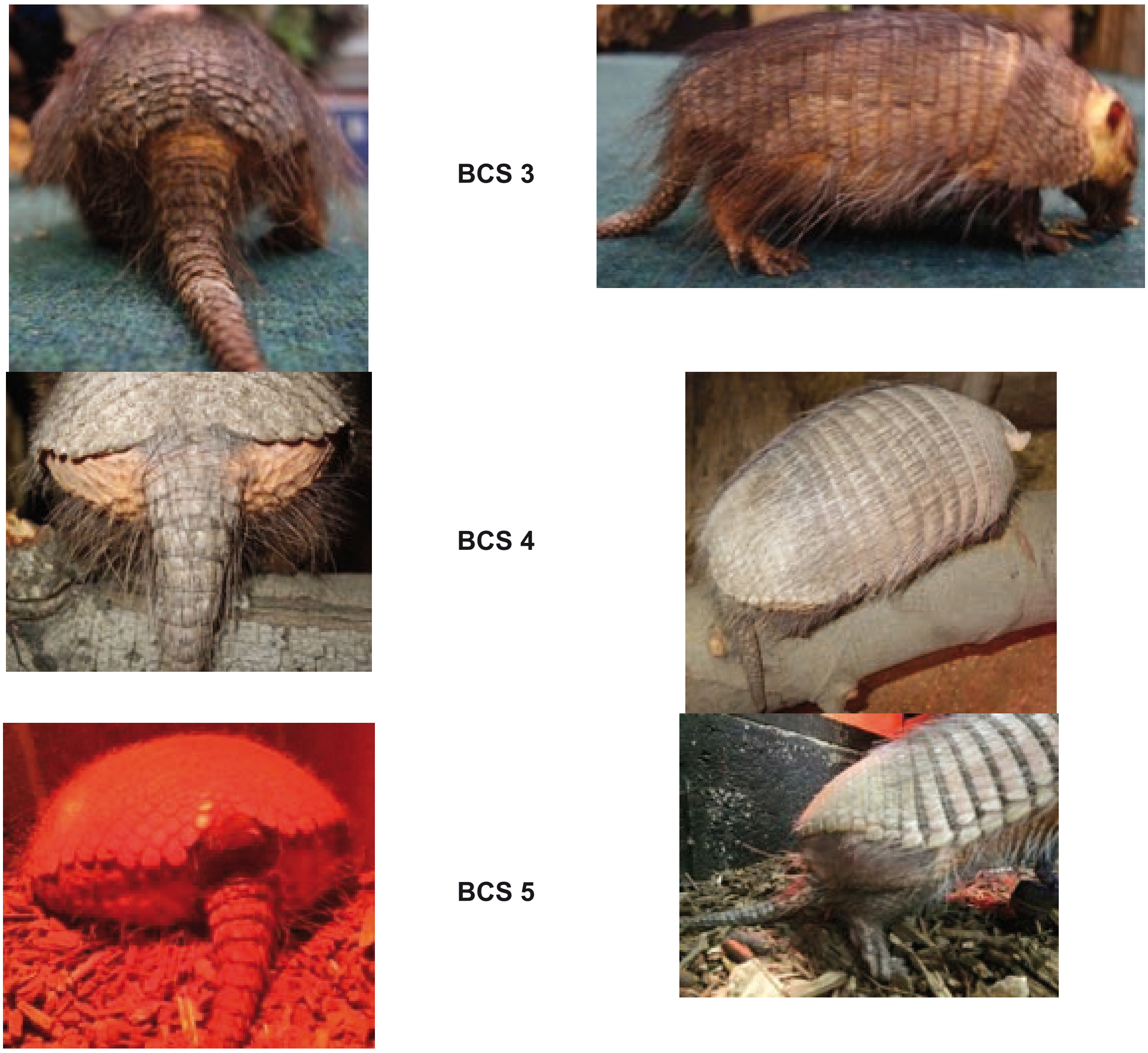

Figure 3. Examples of body condition scores (BCS) in captive large hairy armadillo (*Chaetophractus villosus)* (for a description of the BCS see Table 2). (Photos: A. Clark).

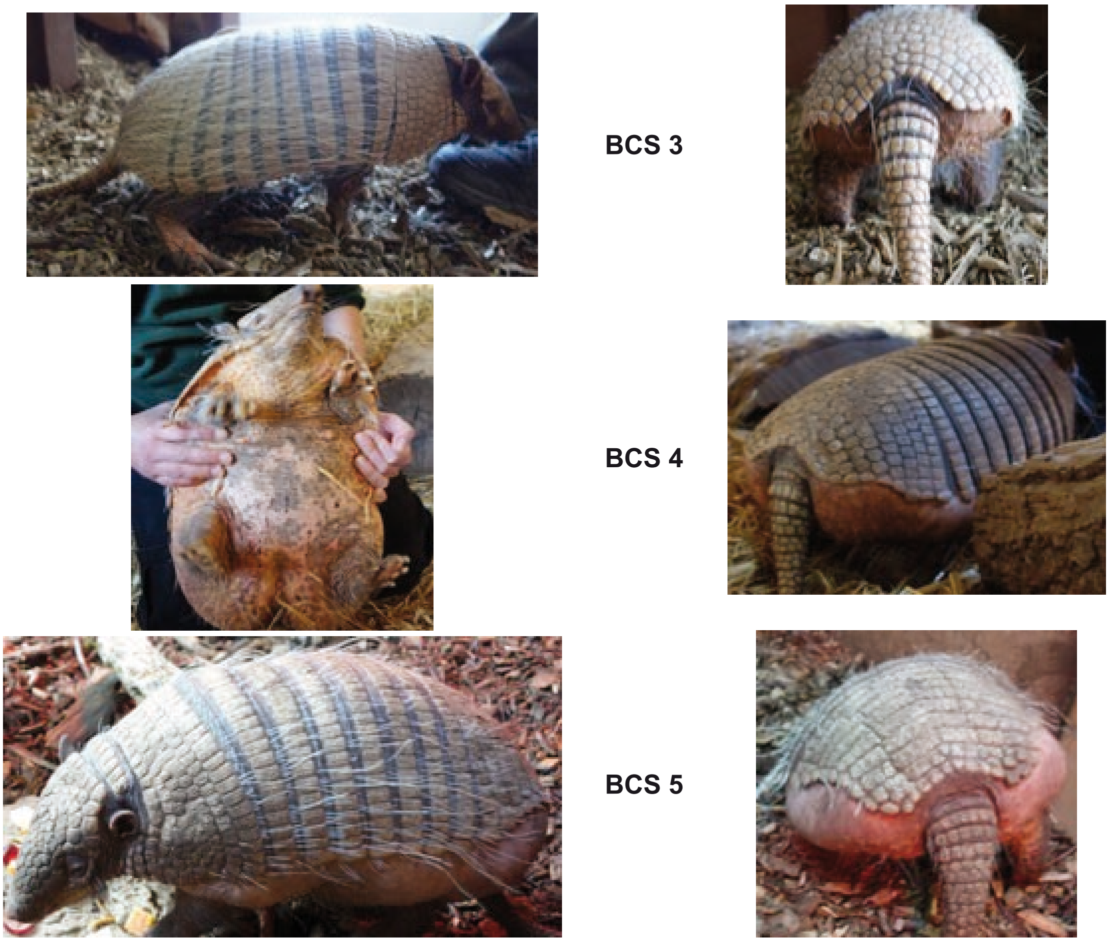

Figure 4. Examples of body condition scores (BCS) in captive yellow/six-banded armadillo (*Euphractus sexcinctus)* (for a description of the BCS see Table 2). (Photos: A. Clark).

BCS was based on the presence of fat above the hips and thighs and on the underside of the dome-shaped shell visible from a lateral and posterior view (Table 2, Figs 3–5). Armadillos and aardvarks were kept in groups, making it difficult to assign faecal specimens to individuals. Thus, faecal samples collected were assigned to the group of individuals and given a faecal score (FS). The FS ranged from firm, dry faeces (1) to diarrhoea-like faeces (5), i.e. a lower FS indicating a better faeces consistency, and was assigned to each defecation sample collected for each individual, or group of individuals, based on photographic evidence using the Waltham® Faeces Scoring System for dogs and cats (Moxham 2001) by one investigator (AC) (Table 3, Figs 6–8). For the FS, a photograph of "normal" faeces from the wild for each species was used as a baseline for comparison (Fig. 9).

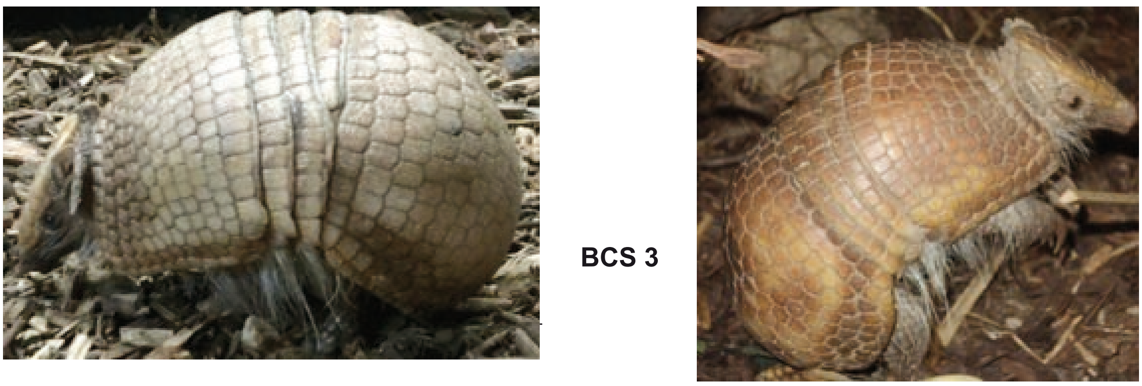

Figure 5. Examples of body condition scores (BCS) in captive Southern three-banded armadillo (*Tolypeutes matacus)* (for a description of the BCS see Table 2). (Photos: A. Clark).

Figure 6. Examples of faecal scores (FS) in captive giant anteaters (*Myrmecophaga tridactyla*) (for a description of the FS see Table 3). (Photos: A. Clark).

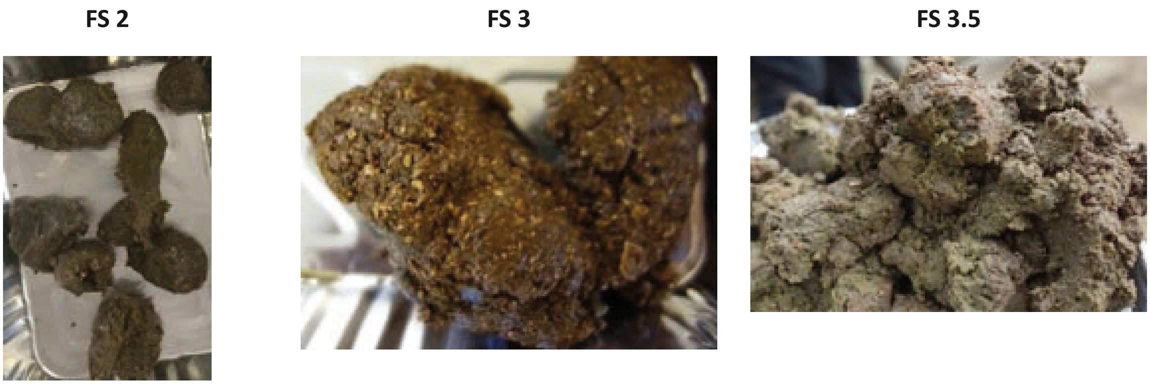

Figure 7. Examples of faecal scores (FS) in captive aardvarks (*Orycteropus afer)* (for a description of the FS see Table 3) (Photos: A. Clark).

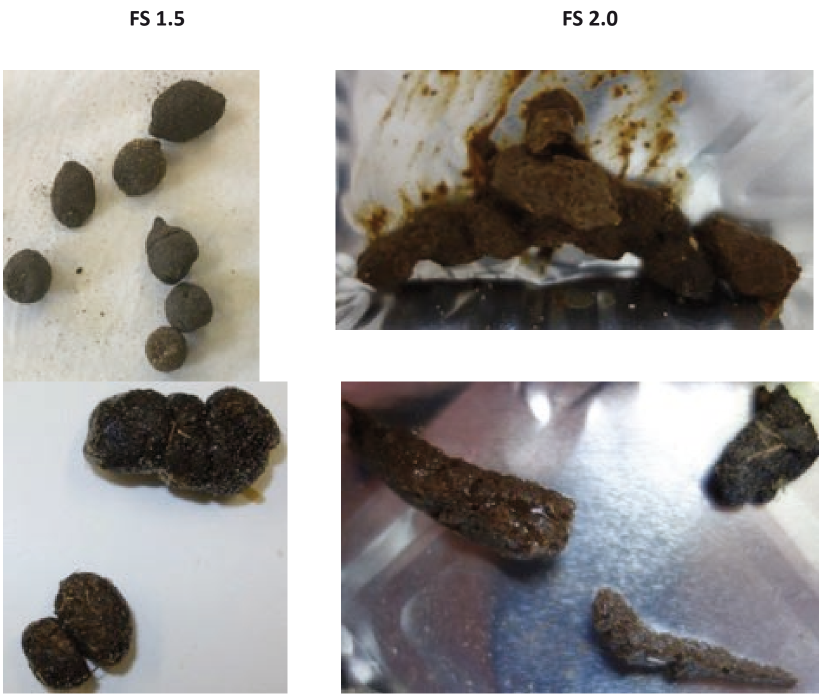

Figure 8. Examples of faecal scores (FS) in captive armadillos (Dasypodidae spp.) (for a description of the FS see Table 3). (Photos: A. Clark).

A B C

Figure 9. Faeces obtained from free-ranging specimen of (A) giant anteater (*Myrmecophaga tridactyla)*, (B) aardvark (*Orycteropus afer)*, and (C) armadillo (Dasypodidae spp.), respectively. (Sources: Photograph A: Möcklinghoff 2008; Photographs B and C: Nebe and Rankin 2010).

Parasitological analysis

Quantitative estimation of worm eggs in the collected faecal samples was conducted via flotation using the Modified McMaster method (MAFF 1986).

Nutrient analyses

Samples were dried at 60° C, ground using a 1 mm screen, and analysed for dry matter (103° C), total ash (AOAC 942.05), acid detergent fibre (ADF) (AOAC 973.18) and AIA (AOAC 955.03) using standard methods (AOAC 2012).

Statistical analyses

Due to the use of ordinal data (scores) and because most data were not normally distributed, simple correlations were tested by Spearman's rho (ρ). Statistical analyses were performed in SPSS 21.0 (SPSS Inc. Chicago, IL), with the significance level set to $P<0.05$.

Results

BCS and body mass

On average, giant anteaters had a higher body mass than any other species, but were offered a smaller amount of diet by dry matter than aardvarks (Table 4). Body mass and the absolute amount of dry matter offered were positively correlated in giant anteaters, but not significantly (ρ=0.611, P=0.061). The average body mass of captive giant anteaters was 49 kg, approximately 4 kg higher than the upper end of normal body mass distribution for wild giant anteaters (31–45 kg); however, there was no consistent difference in the BCS when compared to images of animals in the wild (Table 4, Figs 1 and 10) (Silveira et al. 1999). Body masses were only recorded for 12 out of the 26 giant anteaters from responding collections.

Captive aardvarks had an average body mass of 44.9 kg (Table 4), which is within the range of wild aardvarks (40–60 kg; Taylor

Table 4. Individuum-based data of body mass (kg), body condition score (BCS), dry matter offered (g/d), and relative dry matter offered (g/kg$^{0.75}$/d) at UK collections (means ± standard deviation, range, sample size)[1].

Species	Body mass in adult free-ranging individuals, kg	Body mass, kg	BCS	Dry matter offered, g/d	Relative dry matter offered, g/kg$^{0.75}$/d
Giant anteater (*M. tridactyla*)	31–45[1]	49.0±7.6 (38.5–62.5) n=12	2.9±0.5 (2.0–4.0) n=26	611±214 (270–1170) n=24	30±12 (16–53) n=10
Aardvark (*O. afer*)	40–60[2]	44.9 ± 6.9 (28.6–51.5) n=9	3.0±0.0 (3.0–3.0) n=13	636±102 (445–750) n=13	40±7 (31–55) n=9
Larger hairy armadillo (*C. villosus*)	2.4 (1.0–3.9)[3]	3.8±0.8 (3.0–5.4) n=9	3.7±0.6 (3.0–5.0) n=11	177±115 (58–433) n=9	71±41 (23–148) n=7
Six-banded/yellow armadillo (*E. sexcinctus*)	3.3[4]	7.1±1.3 (5.3–9.5) n=7	4.1±1.1 (3.0–5.0) n=9	138±21 (106–157) n=8	32±7 (23–40) n=6
Southern three-banded armadillo (*T. matacus*)	1.1 (0.8–1.5)[5]	1.3±0.2 (1.0–1.6) n=10	3.0±0.0 (3.0–3.0) n=10	106±47 (72–157) n=5	90±45 (57–156) n=5

[1]Sample sizes vary within species because body masses (kg) were not recorded for all individuals and some dietary samples were not available for collection; [2]Silveira 1969; Möcklinghoff 2008; [3]Smith 2008; [4]Schaller 1983; [5]Smith 2007.

Figure 10. Free-ranging large hairy armadillo (*Chaetophractus villosus*). (Source: Francois Gohier via Wildscreen Arkive).

Figure 11. Free-ranging yellow/six-banded armadillo (*Euphractus sexcinctus)*. (Photo: courtesy of Jon Hall; Jon@mammalwatching.com).

Figure 12. Free-ranging southern three-banded armadillo (*Tolypeutes matacus*). (Photo: courtesy of Jon Hall; Jon@mammalwatching.com).

Figure 13. Free-ranging aardvark (*Orycteropus afer*) moving across the grass. (Source: Ferrero-Labat via Wildscreen Arkive).

Figure 14. Free-ranging giant anteater (*Myrmecophaga tridactyla*). (Source: ©Pete Oxford/naturepl.com).

Table 5. Presence of the individual food items in diets of giant anteater (*Myrmecophaga tridactyla*) and armadillo (Dasypodidae).

	Percentage (number) of collections	
Food items	Armadillo diet	Giant anteater diet
Vegetable mix	88% (15)	8% (1)
Fruit mix	82% (14)	46% (6)
Eggs	59% (10)	38% (5)
Day old chick	53% (9)	–
Dog biscuit	47% (8)	15% (2)
Beef mince	41% (7)	–
Cat biscuit	35% (6)	15% (2)
Zoo "A" pellet[1]	35% (6)	–
Rice	29% (5)	–
Termant[1]	24% (4)	92% (12)
Mice	18% (3)	–
Older chickens	6% (1)	–
Mixed nuts	6% (1)	–
Brown bread	6% (1)	–
Cheese	6% (1)	–
Yogurt	6% (1)	15% (2)
Starch mix	6% (1)	–
Honey	–	46% (6)
Peat	–	31% (4)
Beef heart	–	23% (3)
Dry shrimp	–	15% (2)
Porridge oats	–	15% (2)
Dog food (tinned)	–	8% (1)
Horse minced meat	–	8% (1)
Leaf-Eater Primate Diet[1]	–	8% (1)

[1]Mazuri Zoo Foods, Witham, Essex, UK

et al. 2002), had a similar BCS and were of similar size and shape when compared to images of free ranging aardvarks (Figs 2 and 11). There was a negative correlation between body mass and the relative amount of dietary dry matter offered in aardvarks (ρ=-0.739, P=0.023).

A significant correlation between body mass and BCS only occurred in *E. sexcinctus* (ρ=0.791, P=0.034). Obese (BCS >4) individuals were observed in *C. villosus* and *E. sexcinctus* (Figs 3–4). The average body mass of *C. villosus* and *E. sexcinctus* representatives were 3.8 kg and 7.1 kg, respectively, with these captive individuals being noticeably larger when compared to images of free-ranging individuals (Table 4; Figs 12–13). Captive *T. matacus* (average body mass: 1.3 kg) did not appear obese when compared to free-ranging individuals, whose average body mass in the wild is 1.1 kg (Smith 2007) (Figs 5 and 14).

Ingredients and analytical composition of the diets

There were large differences in the amount of dry matter offered between institutions (up to seven-fold in *C. villosus*, Table 4). Out of the 13 collections keeping giant anteaters, 54.0% used Termant,

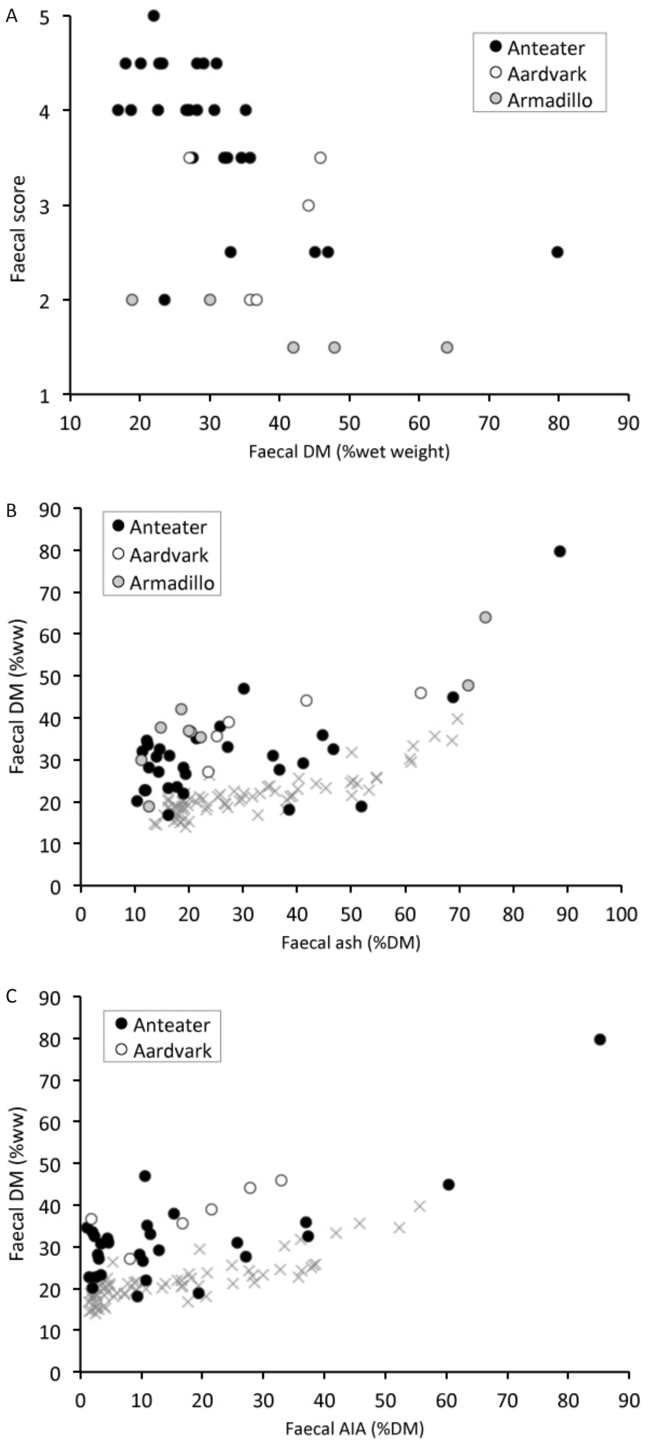

Figure 15. Relationship between A) faecal dry matter (DM) content and faecal score, B) faecal total ash content and faecal DM content, and C) faecal acid insoluble ash (AIA) content and faecal DM content in the captive giant anteaters (*Myrmecophaga tridactyla*), aardvarks (*Orycteropus afer*) and armadillos (Dasypodidae spp.) in the UK facilities represented in the present study, compared to data from giant anteaters from Gull et al. (2015; grey crosses).

23.0% traditional gruel mixed with Termant and sieved peat, 7.7% traditional gruel mix, 7.7% gruel mix combined with Termant, 7.7% traditional gruel mixed with Termant, peat, and Leaf-Eater Primate Diet (Mazuri Zoo Foods). The ingredients of these diets are listed in Table 5. All five collections keeping aardvarks used exclusively Termant with no additives. There was a large variety in armadillo diets (Table 5), with only two out of 17 (11.8%) collections feeding individuals a similar diet of rice, seasonal fruit and vegetable mix, dog biscuit, cat biscuit, mince, and Mazuri Omnivore–Zoo Feed "A" pellets (Mazuri Zoo Foods). Overall diets for aardvarks had a higher average diet ADF when compared to giant anteaters, and both species had higher ADF levels compared to armadillos (Table 6). All species received diets with similar average AIA values (Table 6). For all species, insects (waxworms, mealworms, and crickets) were fed as treats/behavioural enrichment.

Table 6. Total ash, acid detergent fibre (ADF) and acid insoluble ash (AIA) content (all values in % dry matter (DM)) of diets fed to different species of myrmecophageous mammals in UK facilities (means ± standard deviation, range, sample size).

Species	Total ash % of DM	ADF % of DM	AIA % of DM
Giant anteater (*M. tridactyla*)	6.3±1.3 (4.5–10.2) n=13	20.5±5.2 (5.4–25.0) n=13	0.5±0.1 (0.4–0.9) n=13
Aardvark (*O. afer*)	7.1±1.8 (6.2–10.3) n=5	21.6±1.0 (19.9–22.0) n=5	0.4±0.2 (0.0–0.6) n=5
Larger hairy armadillo (*C. villosus*)	5.9±0.9 (4.6–6.4) n=6	11.3±7.3 (6.2–22.0) n=6	0.4±0.1 (0.3–0.5) n=6
Six-banded/yellow armadillo (*E. sexcinctus*)	7.2±1.7 (4.6–8.6) n=5	9.5±3.1 (6.2–14.3) n=5	0.5±0.1 (0.3–0.7) n=5
Southern three-banded armadillo (*T. matacus*)	5.6±0.9 (4.6–6.2) n=5	14.5±10.6 (6.2–22.0) n=5	0.4±0.1 (0.3–3.5) n=5

Faecal scores and composition

Compared to aardvarks and armadillos, faecal scores for giant anteaters were higher, indicating less well-formed faeces (Table 7). There were no significant correlations between dietary contents of either total ash, ADF, AIA, or the sum of AIA and ADF with FS and with faecal DM content (P>0.10 in all cases) (Tables 6 and 7).

There was a negative overall correlation between the faecal dry matter content and FS (Fig. 15A; ρ=-0.615, P<0.001). Faecal dry matter content increased with both faecal total ash (Fig. 15B; ρ=0.486, P=0.001) and faecal AIA concentration (Fig. 15C; ρ=0.447, P=0.009); in these relationships, a similar pattern as in the data for giant anteaters from Gull et al. (2015) was observed (background data in Fig. 15B and C), but on a slightly higher DM level. As expected from these relationships, faecal ash concentration was also negatively correlated to the faecal score (Fig. 16A; ρ=-0.285, P=0.049), and for faecal AIA, there was a trend for a negative correlation with faecal score (Fig. 16B; ρ=-0.359, P=0.060).

Parasitology

Out of the 32 faecal samples from giant anteaters and aardvarks analysed, only one individual giant anteater tested positive for worm eggs, specifically *Capillaria* sp. The positive individual had an FS of 5, and was excluded from the faecal analysis results.

Discussion

This study provides survey data on diets, body mass, body condition and faecal scores for captive giant anteaters, aardvarks, and three species of armadillo in UK collections. The findings document known difficulties in keeping these animals, little consistency in the amounts fed across facilities, and indicate that

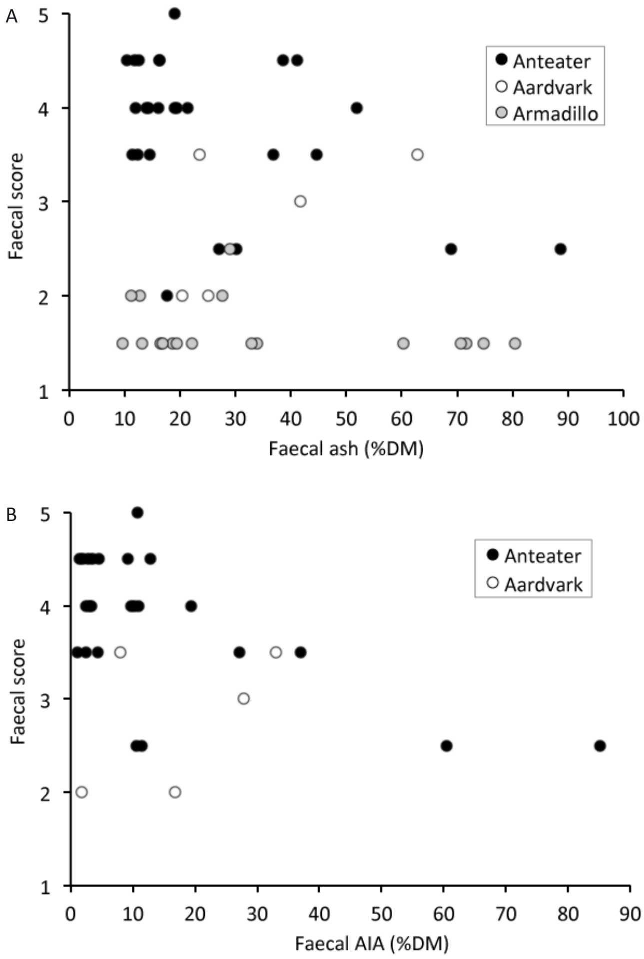

Figure 16. Relationship between A) faecal total ash content and faecal score, and B) faecal acid insoluble ash (AIA) content and faecal score in the captive giant anteaters (*Myrmecophaga tridactyla*), aardvarks (*Orycteropus afer*) and armadillos (various spp.) in the UK facilities of the present study.

diets used to date may lead to poor faecal consistency, specifically in giant anteaters.

With only 35 collections housing myrmecophages in the UK, an important factor of this study limiting the statistical power was the number of facilities available to survey. The logistical scope of this study did not allow quantification of actual diet intake by individual animals, but simply the recording of amounts offered, which might have prevented relationships between BCS or body mass and amounts fed to become evident. Additionally, the effects of diets could not be evaluated comprehensively due to the limited variety of diets offered in the facilities sampled. Therefore, experimental approaches with more distinct dietary variation may be required to identify the impact of diet on faecal consistency. In particular, as shown by Gull et al. (2015) for giant anteaters, the actual intake of myrmecophages may differ distinctly from the diet offered due to the additional ingestion of soil, sand or debris from their enclosures. In the case of armadillos, faecal samples were too small for analysis of ADF, AIA, and parasite burden.

Diet

Initial attempts to create nutritionally acceptable high protein diets for anteaters resulted in captive diets consisting of horsemeat, Purina Mink Developer Chow, and the addition of protein powder, mineral powder, and vitamin K blended or mixed with canned or whole milk to form a semi-soft solid feed (Meritt 1976, 1977; Edwards and Lewandowski 1996). Currently, the majority of UK collections are feeding their myrmecophages on a complete insectivore diet, following similar trends seen in North America: 92% of the UK collections housing giant anteaters and 100% of the collections housing aardvarks are using Termant now. Though still present in the diets of some collections, lactose and grain products are used significantly less than in the past, which may be because they contribute to soft faeces (Edwards and Lewandowski 1996; Valdes and Brenes Soto 2012; Gull et al. 2015). Termant, fruit, honey, egg, and peat compromise the majority of the diets for *M. tridactyla,* different to the results of Morford and Meyers' (2003) US diet survey, which showed that leaf-eater pellet, dry dog food, and dry cat food were the most common ingredients.

Table 7. Faecal consistency scores, and faecal contents of dry matter (DM), total ash, and acid insoluble ash (AIA) in samples (means ± standard deviation, range, sample size).

Species	Faecal score	DM % of wet weight	Total ash % of DM	AIA % of DM
Giant anteater (*M. tridactyla*)	3.9±0.8 (2.0–5.0) n=22	30.6±11.4 (16.9–79.8) n=30	28.1±20.3 (10.4–88.6) n=31	17.1±21.5 (1.1–85.1) n=28
Aardvark (*O. afer*)	2.8±0.7 (2.0–3.5) n=13	38.1±6.7 (27.2–45.9) n=6	33.5±16.2 (20.3–62.8) n=6	18.2±11.8 (1.9–33.0) n=6
Larger hairy armadillo (*C. villosus*)	1.5±0.0 (1.5–1.5) n=11	49.1±14.3 (35.4–64.0) n=6	45.9±25.5 (19.5–74.8) n=6	N/A
Six-banded/yellow armadillo (*E. sexcinctus*)	1.7±0.3 (1.5–2.0) n=9	28.6±7.8 (19.0–36.8) n=6	20.6±9.2 (11.2–33.9) n=6	N/A
Southern three-banded armadillo (*T. matacus*)	1.5±0.0 (1.5–2.0) n=10	42.0 n=1	N/A	N/A

N/A = not analysed (due to low sample volume).

There was great variation in nutritional values from complete insectivore diet and traditional gruel when compared to the stomach contents of free-ranging tamandua (*Tamandua tetradactyla)* – currently the only available comparative data for a free-ranging anteater. On a DM basis, the diet of wild tamandua consists of 14.0% ash and 31.0% ADF (Oyarzun et al. 1996). In contrast, the ash and ADF content in captive giant anteaters, aardvarks, and armadillo averaged 6.3% ash and 20.5% ADF; 7.1% ash and 21.6% ADF; and 5.6–7.2% ash and 9.5–14.5% ADF, respectively. Accordingly, the diet of free-ranging individuals contains almost twice the amount of ash and ADF compared to those surveyed in the present study. The potential consequences of these differences could be that captive myrmecophages are lacking indigestible material in their diets, which could contribute to soft faeces (Steinmetz et al. 2007; Stahl et al. 2012; Wyss et al. 2013; Gull et al. 2015). Though soft faeces do not necessarily imply that there is a health problem (Gull et al. 2015), further experiments assessing the addition of indigestible material (i.e. peat, sand, etc.) is recommended. The lack of correlation between dietary total ash, dietary ADF, dietary AIA, or the sum of dietary AIA and ADF with faecal scores or faecal DM, is similar to results found in a survey study on captive tapirs (*Tapirus* spp.) that reported no correlation between the average FS and nutrient levels (Clauss et al. 2009), and may result from extra intake of ash and AIA from non-dietary sources such as soil.

Diets for captive armadillo have remained virtually unchanged when compared with historical diets consisting of a mixture of meat, dog biscuit, eggs, honey, molasses, and multivitamins and minerals (Meritt 1977). Collections still use the same basal diet but now have additional starch, fruit, and vegetable components. It has been found that fruit is selectively ingested when available and plants have been found to be an important dietary component of *E. sexcinctus* in the wild (Da Silveira Anacleto 2007).

Body masses and BCS

Body masses of the captive giant anteater, large hairy armadillo and yellow/six-banded armadillo were higher than those observed in the wild, while those of aardvark and three-banded armadillo were not. The average body mass recorded for captive giant anteaters was 49 kg, whereas the body mass of free-ranging individuals rarely exceeds 40 kg (Shaw et al. 1987; Medri and Mourão 2005). Body mass and absolute amount of dry matter offered was positively correlated in giant anteaters, although not quite significantly.

There were differences in the BCS of some captive giant anteaters when compared to photographs of those in the wild, particularly in the neck and hips of individuals. Some captive individuals appear to have thicker necks with more prominent fat rolls and more rounded hips than those in the wild; however, none of the captive giant anteaters in this survey was categorised as grossly obese (i.e. BCS 5; presence of excessive fat). The question has been raised as to whether higher body masses in captive giant anteaters indicate not only simply obesity due to overfeeding and inadequate exercise, but also increased growth rates or extended longer growth than in the wild due to the constant high food supply (Stahl et al. 2012). The lack of a correlation between BCS and body mass in giant anteaters in the present study could be considered as supporting the increased/extended growth hypothesis. Because most free-ranging myrmecophages, including the giant anteater, have seasonal variation in their diets, they may have physiological adaptations to building fat reserves in order to survive periods where food availability is scarce (Redford 1986; Taylor et al. 2002; Möcklinghoff 2008). Zoo feeding regimes may not mimic such seasonal variation. In addition, commercial diets, such as Termant, are comparatively energy dense, which can lead to weight gain (Hosey et al. 2013). Only 12 of the 26 giant anteaters had records of body masses at their collection. Training of individuals of these species to allow for regular body mass checks would be ideal for monitoring nutrition and the prevention of obesity. In particular, measurements of body mass and shoulder height (or some other measure of structural body size) taken in the same individuals from captivity and the wild would be important to distinguish between obesity and increased growth. Alternatively, means to quantify adipose tissue in captivity, such as standardised ultrasound examinations, would help clarify the issue but might entail manipulation of the animals' fur and hence appearance that make them undesirable.

Captive aardvarks were not considered obese when compared to free-ranging individuals. The average body mass of captive aardvarks was 44.9 kg, whereas body masses range between 40 and 60 kg in the wild (Taylor et al. 2002; Knothig 2005). There were no notable differences observed in BCS when comparing captive individuals amongst each other and to those in the wild. The solitary and strictly nocturnal behaviour of aardvarks makes them difficult to observe, so most information is anecdotal, including the amount of food they ingest (Taylor et al. 2002; Knothig 2005). In contrast to the giant anteater, body mass and BCS were negatively correlated to the relative amount of dry matter offered in captive aardvarks, but the low sample size most likely makes this a spurious result. The correlations observed when assessing the relative amount of dry matter offered could be a result of limitations common to survey studies. With the aardvarks, keepers might have been reacting and offering higher volumes of food to thinner animals; with the giant anteaters, animals that had been fed more might have become heavier.

On average, per unit of metabolic body weight, giant anteaters were offered less dry matter than aardvarks. This is probably due to the difference in basal metabolic rates (BMR) between the species. Giant anteaters have a BMR of 96 kJ/kg$^{0.75}$/d, while aardvarks have a BMR of 162 kJ/kg$^{0.75}$/d (McNab 2008). Thus the requirements of giant anteaters for energy per unit of metabolic body weight are only 59% of those of aardvarks. However, giant anteaters were on average provided with 75% of the dry matter offered to aardvarks per unit metabolic body mass in the present survey. Thus, they were probably offered more dry matter relative to their basal metabolic needs. In spite of this, Termant's maintenance feeding recommendations suggest that giant anteaters should be fed a larger quantity per unit mass than aardvarks. It is uncertain what the rationale was when Mazuri created their maintenance feeding guidelines for these species, or whether published BMR data (McNab 2008; Stahl et al. 2012) were used. Future studies measuring the digestible or metabolisable energy contents for diets are recommended, which could be undertaken using conventional nutrient analysis and standard equations for domestic carnivores as demonstrated in Gull et al. (2015).

The southern three-banded armadillo (*Tolypeutes matacus*) was the only armadillo species that had normal BCS and did not show signs of obesity. The average body mass for individuals surveyed was 1.3 kg, which is above the recorded average of 1.1 kg for those in the wild (Smith 2007). The average body mass of captive *C. villosus* and *E. sexcinctus* were 3.8 kg and 7.1 kg, respectively. These weights were more than 2 kg heavier when compared with those for wild caught *C. villosus* and *E. sexcinctus* weighing 2.37 kg and 3.30 kg, respectively (Schaller 1983; Smith 2008). The average BCS for these individuals were 3.7 and 4.1. Individuals of these species in captivity showed obvious signs of obesity; specifically, the presence of excessive fat pockets around their hips and sides was observed, which pushed the shell upwards. This is an uncommon characteristic in free-ranging individuals. Most individuals were fed twice a day, though commonly, a substantial portion of food was left after every feeding (pers. obs.). Armadillos are also known to have a lower BMR than most mammals, making them susceptible to obesity and overfeeding in captivity (McNab 2008; Superina and Loughry 2011). Obesity can have a negative effect on the welfare and well-being of captive individuals, leading to issues such as limb lameness and reproductive problems (Hosey et al. 2013). Though the overall nutritional requirements of armadillos are unknown, the overall quantity of food offered should be reviewed in order to prevent nutritional disorders in the future and reduce the number of obese individuals in captivity.

Properties of the faeces

Aardvarks and armadillo defaecate rounded, "pelleted" droppings that have a layer of dirt on the outside, which is primarily composed of ingestible material (Talmage and Buchanan 1954; Chame 2003). As in the wild (Talmage and Buchanan 1954; Taylor et al. 2002; Knothig 2005), captive aardvarks in this study were observed to deposit small ovoid pellets in large accumulations that were buried at depths of up to 10 cm in the ground. The FS for aardvark and armadillo (Dasypodidae) individuals were similar to those found in the wild when compared to photographs and literature. Locating faecal samples for the aardvarks and armadillos was challenging and made multiple collections for these species difficult.

Unlike in the aardvark and armadillo, soft faeces have been an ongoing issue for captive giant anteaters (Edwards and Lewandowski 1996; Morford and Meyers 2003b; Steinmetz et al. 2007; Gull et al. 2012, 2015; Stahl et al. 2012; Valdes and Brenes Soto 2012; Wyss et al. 2013). The results of this study (with an average FS of 4) are qualitatively similar to the impression reported by Bissel (2015) at the Pangolin, Aardvark and Xenarthan Taxon Advisory Group that faeces of a cow-pie and formless patty consistency are currently most often observed in US institutions. The difference is unlikely to be founded in digestive anatomy: though limited, studies have shown that giant anteaters have similarities and differences in their digestive physiology when compared to armadillos and aardvarks. Armadillos and anteaters have similarly short intestines and no caecum, whereas the aardvark is known to have a larger caecum compared to most insectivores (Stevens and Hume 2004; Knothig 2005).

The hypothesis that faecal DM, ash and AIA contents correlate with FS was confirmed, indicating that the FS at least partially reflects faecal dry matter content. The expected relationship between faecal dry matter and faecal ash suggests that means to increase faecal ash contents will help improve faecal consistency (Gull et al. 2015). The magnitude of the data on faecal composition in this study resembled that determined by Gull et al. (2015) (Fig. 15).

Dietary composition had no measurable influence on faeces in the present study. The faecal data were in accord with Gull et al. (2015), where AIA content of offered diets did not correlate with faecal DM content; rather, the reconstructed overall AIA intake (from diet and from enclosure soil) showed such a correlation. This suggests that higher amounts of indigestible material in diets or foods rich in fibre might improve faecal consistency. Studies looking at the nutrient composition of stomach samples from wild giant anteaters would help to determine the amount of indigestible material present. Soil and sand found in faeces of wild giant anteaters may be an important contributor to faecal consistency (Möcklinghoff 2008; Gull et al. 2015). Other potential reasons for unfavourable faecal consistency in giant anteaters should be investigated in future studies. For example, linking faecal scores to behavioural observations and to levels of corticosteroid metabolites in the same faecal samples could reveal the presence or absence of an influence of a general "stress level" on faecal consistency.

Parasitology results were consistent with past findings that severe, watery diarrhoea is usually caused by infectious pathogens and is not a result of diet (Gull et al. 2015); this was observed in the single individual with a FS of 5. Due to timing constraints, the modified McMaster method was used for counting parasite eggs; however, FLOTAC is recommended *in lieu* of the McMaster method for future parasite screenings due to the technique having a greater sensitivity and reproducibility (Rinaldi et al. 2011). Although the results must be considered with these restrictions in mind, they suggest that parasites did not play a major role in the health of the UK captive giant anteater and aardvark population at the time of investigation.

Conclusions

1. In a survey study investigating the feeding practices of myrmecophages in captive UK collections, we found that the majority of collections offer a complete feed for their giant anteaters and aardvarks.
2. There was a significant correlation between body mass and BCS for yellow/six-banded armadillos, but not for any other species. Obesity was observed in individual large hairy and yellow/six-banded armadillos. Neither body mass nor BCS were significantly correlated with the relative amount of dry matter offered. Careful monitoring of body masses and diets for the giant anteater as well as for armadillos is encouraged, in order to avoid obesity. Comparing the energy contents of various diets offered, and adjusting the corresponding feeding amounts to energetic requirements, is recommended.
3. As in previous studies, no correlations were found between dietary total ash, ADF, AIA, or the sum of dietary AIA and ADF with the FS or the faecal DM. There was a negative correlation between faecal dry matter content and FS. Faecal dry matter increased with faecal total ash and faecal AIA concentration. Faecal ash concentration was negatively correlated to the FS. For faecal AIA, there was a trend for a negative correlation with FS. Measures that increase faecal ash and AIA concentrations, such as providing diets high in indigestible ash sources, are likely to improve FS. Further studies are needed to investigate the effects of higher amounts of indigestible matter (i.e. diets reduced in energy content) in anteaters on faecal consistency, growth, and body condition.
4. Only one individual exhibited a patent parasite infection (for *Capillaria* sp.), and a diarrhoea-type faecal consistency (FS of 5). Parasites apparently play a minor role under current husbandry practices for giant anteaters and aardvarks in the UK.

Acknowledgements

We thank Tony Sainsbury, Michael Waters and Andrew Mackie at RVC for their support in the overall arrangements for this study, and Carmen Kunz, Muna Mergani, and Peter Stirnemann from the ETH Zurich for guidance in lab analyses. We are especially grateful to BIAZA for endorsing this project and to the twenty zoological collections and their dedicated keepers for their valuable support and assistance during this study (in alphabetical order): Africa Alive, Amazon World, Banham Zoo, Beale Park, Belfast Zoological Gardens, Blackpool Zoo, Chessington World of Adventures, Colchester Zoo, Cotswold Wildlife Park, Edinburgh Zoo, Exmoor Zoological Park, Folly Farm Leisure, Howlett's Wild Animal Park, London Zoo, Longleat Safari, Manor House Wildlife Park, Marwell Zoo, Paradise Wildlife Park, Shepreth Wildlife Park, and Yorkshire Wildlife Park.

References

AOAC (2012) *Official Methods of Analysis of AOAC International.* Gaithersburg, MD: AOAC International.

Bissel H. (2015) Giant anteater (*Myrmecophaga tridactyla*) fecal scoring scale. www.paxtag.ort/wp-content/uploads/2015/09/Giant-Anteater-Feces-Scoring-Scale.pdf (accessed 30.01.2016)

Camilo-Alves CDSEP, Mourão G.D.M. (2006) Responses of a specialized insectivorous mammal (*Myrmecophaga tridactyla*) to variation in ambient temperature. *Biotropica* 38: 52–56.

Chame M. (2003) Terrestrial mammal feces: a morphometric summary and description. *Memorial Institute Oswaldo Cruz* 98: 71–94.

Clauss M., Wilkins T., Hartley A., Hatt J.-M. (2009) Diet composition, food intake, body condition, and fecal consistency in captive tapirs (*Tapirus* spp.) in UK collections. *Zoo Biology* 28: 279–291.

Da Silveira Anacleto TC. (2007) Food habits of four armadillo species in the Cerrado area, Mato Grosso, Brazil. *Zoological Studies* 46: 529–537.

Delsuc F., Metcalf J.L., Wegener Parfrey L., Parfrey L.W., Song S.J., Gonzalez A., Knight R. (2014) Convergence of gut microbiomes in myrmecophagous mammals. *Molecular Ecology* 23: 1301–1317.

Diniz L.S.M., Costa E.O., Oliveira P.M.A. (1995) Clinical disorders observed in anteaters (*Myrmecophaga edentata*) in captvity. *Veterinary Research Communications* 19: 409–415.

Edwards M., Lewandowski A. (1996) Preliminary observations of a new diet for giant anteaters (*Myrmecophaga tetradactyla*). *Annual Conference of the American Association of Zoo Veterinarians*: 496–498.

Gull J., Rothlin T., Clauss M., Hatt J.-M. (2012) Never give up: changing giant anteaters (*Myrmecophaga tridactyla*) to a new, complete diet at Zurich Zoo. *7th European Zoo Nutrition Conference*, Zurich 2012, 4.

Gull J.M., Stahl M., Osmann C., Ortmann S., Kreuzer M., Hatt J.-M., Clauss M. (2015) Digestive physiology of captive giant anteaters (*Myrmecophaga tridactyla*): determinants of faecal dry matter content. *Journal of Animal Physiology and Animal Nutrition* 99: 565–576.

Hosey G., Melfi V., Pankhurst S. (2013) *Zoo Animals: Behaviour, Management, and Welfare*. Oxford: Oxford University Press.

Knöthig, J. (2005). *Biology of the Aardvark (*Orycteropus afer*).* MSc thesis. Heidelberg, Germany: Ruprecht-Karls-Universität.

McNab B.K. (1984) Physiological convergence amongst ant-eating and termite-eating mammals. *Journal of Zoology* 203: 485–510.

McNab B.K. (2008) An analysis of the factors that influence the level and scaling of mammalian BMR. *Comparative Biochemistry and Physiology Part A* 151: 5–28.

Medri Í.M., Mourão G. (2005) Home range of giant anteaters (*Myrmecophaga tridactyla*) in the Pantanal wetland, Brazil. *Journal of Zoology* 266: 365–375.

Meritt D.A. (1976) The nutrition of edentates. *International Zoo Yearbook* 16: 38–46.

Meritt Jr, D.A. (1977) Edentate nutrition. *CRC Handbook Series in Nutrition and Food* 1: 541–547.

Ministry of Agriculture, Fisheries and Food (1986) *Manual of Veterinary Parasitological Laboratory Techniques* (Reference Book 418). London: Her Majesty's Stationery Office.

Möcklinghoff L. (2008). Social organization and habitat use of the giant anteater (*Myrmecophaga tridactyla* L.,1758) in timber plantations in northern Brazil. *Faculty of Biology, Department of Animal Ecology and Tropical Biology. Julius-Maximilians University Würzburg, Würzburg* 127.

Morford S., Meyers M. (2003) Giant anteater (*Myrmecophaga tridactyla*) diet survey. *Edentata* 5: 20–24.

Moxham G. (2001) "The WALTHAM" feces scoring system – a tool for veterinarians and pet owners: How does your pet rate? *Waltham Focus* 11: 24–25.

Nebe B., Rankin P. (2015) Pangolin Research Mundulea. In: *Pangolin Survival Strategies in Dry-land Savannahs: a Pilot Study in Namibia: Pangolin Scats*. http://pangolins-namibia.blogspot.ch/2010/12/pangolin-scats.html.

Oyarzun S.E., Crawshaw G.J., Valdes E.V. (1996) Nutrition of the tamandua: I. Nutrient composition of termites (*Nasutitermes* spp.) and stomach contents from wild tamanduas (*Tamandua tetradactyla*). *Zoo Biology* 15: 509–524.

Redford K.H. (1986) Dietary specialization and variation in two mammalian myrmecophages (variation in mammalian myrmecophagy). *Revista Chilena Historia Natural* 59: 201–208.

Redford K.H. (1987). Ants and termites as food. *Current Mammalogy* 1987: 349–399).

Reiss K.Z. (2001) Using phylogenies to study convergence: The case of the ant-eating mammals. *American Zoologist* 41: 507–525.

Rinaldi L., Coles G.C., Maurelli M.P., Musella V., Cringoli G. (2011) Calibration and diagnostic accuracy of simple flotation, McMaster and FLOTAC for parasite egg counts in sheep. *Veterinary Parasitology* 177: 345–52.

Schaller G.B. (1983) Mammals and their biomass on a Brazilian ranch. *Arquivos de Zoologia* 31: 1–36.

Shaw J.H., Machado-Neto J., Carter T.H. (1987) Behavior of free-living giant anteaters (*Myrmecophaga tridactyla*). *Biotropica* 19: 255–259.

Silveira E.K.P. (1969) História natural do tamanduá-bandeira, *Myrmecophaga tridactyla* L. 1758, Myrmecophagidae. *Velozia* 7: 34–43.

Silveira L., De Almeida Jácomo A.T., Diniz Filho J.A.F., Rodrigues F.H.G. (1999) Impact of wildfires on the megafauna of Emas National Park, central Brazil. *Oryx* 33: 108–114.

Smith P. (2007) Southern three-banded armadillo. *FAUNA Paraguay Handbook of the Mammals of Paraguay*, 1–12.

Smith P. (2008) Greater hairy armadillo *Chaetophractus villosus* (Desmarest, 1808). *FAUNA Paraguay Handbook of the Mammals of Paraguay*, 1–15.

Stahl M., Osmann C., Ortmann S., Kreuzer M., Hatt J.-M., Clauss, M. (2012) Energy intake for maintenance in a mammal with a low basal metabolism, the giant anteater (*Myrmecophaga tridactyla*). *Journal of Animal Physiology and Animal Nutrition* 96: 818–824.

Steinmetz H.W., Clauss M., Feige K., Thio T., Isenbügel, E., Hatt J.-M. (2007) Recurrent tongue tip constriction in a captive giant anteater (*Myrmecophaga tridactyla*). *Journal of Zoo and Wildlife Medicine* 38: 146–149.

Stevens C.E., Hume I.D. (2004) The mammalian gastrointestinal tract In: Stevens C.E., Hume I.D. (eds). *Comparative Physiology of the Vertebrate Digestive System.* Cambridge, UK: Cambridge University Press.

Superina M., Loughry W.J. (2011) Life on the half-shell: Consequences of a carapace in the evolution of armadillos (Xenarthra: Cingulata). *Journal of Mammalian Evolution* 19: 217–224.

Talmage R.V., Buchanan G.D. (1954) The armadillo (*Dasypus novemcinctus*): A review of its natural history, ecology, anatomy and reproductive physiology. *The Rice Institute Pamphlet* 41: 1–12.

Taylor W.A., Lindsey P.A., Skinner J.D. (2002) The feeding ecology of the aardvark *Orycteropus afer*. *Journal of Arid Environments* 50: 135–152.

Valdes E.V., Brenes Soto A. (2012) Feeding and nutrition of anteaters. In: Miller R.E., Fowler M. (eds). *Fowler's Zoo and Wild Animal Medicine,* 7th edn. St. Louis, Missouri: Saunders 378–383.

Wyss F., Gull J., Rothlin T., Scheiwiler T., Clauss M., Hatt J.-M. (2013) Observations on weight loss and fecal consistency in giant anteaters (*Myrmecophaga tridactyla*) during three transitions from a mixed natural in-house to commercial complete diets. In Proceedings of the American Association of Zoo Veterinarians 20–22.