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Managing repetitive locomotor behaviour and time spent off exhibit in a male black-footed cat (*Felis nigripes*) through exhibit and husbandry modifications

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Keywords:
dietary modification, exhibit modification, feeding schedule, science-based management, stereotypic behaviour

Article history:
Received: 1 September 2015
Accepted: 4 April 2016
Published online: 30 April 2016

Abstract

At Cleveland Metroparks Zoo (Cleveland, OH, USA) a male black-footed cat was frequently observed to exhibit repetitive locomotor behaviour and spent a large portion of his day off exhibit. As part of a collaborative effort between animal care and research staff, a stepwise intervention strategy was developed to decrease the subject's repetitive locomotion and increase his time spent on exhibit. This plan consisted of four phases: baseline, the implementation of a random feeding schedule, exhibit modification, and the implementation of a low-starch diet. The implementation of the low-starch diet resulted in a significant decrease in locomotor behaviour and beginning with the first manipulative phase a qualitative decrease in repetitive locomotor behaviour was observed. Following the implementation of these changes, the subject also significantly decreased his time spent off exhibit. This is the first systematic study addressing an animal welfare concern in a black-footed cat.

Background

Stereotypic behaviour (i.e. repetitive, invariant and functionless behaviour) is often considered a sign of suboptimal welfare (Mason and Mendl 1993; Mason 1991), however, these behaviours can be habitual and/or a remnant of past experience(s) (Mason and Latham 2004). As a taxon, carnivores commonly exhibit stereotypic behaviour, but there are clear species differences (Clubb and Mason 2003). In the wild, carnivores spend a significant portion of time hunting, and frustrated appetitive foraging behaviour may emerge and manifest into stereotypic behaviour if an individual is not capable of exhibiting species-typical hunting behaviour (Carlstead 1998; Clubb and Mason 2003). Random feeding schedules have been used to provide a more species-appropriate feeding opportunity for carnivores in zoos. This method has decreased stereotypic behaviour in several carnivore species (tiger, *Panthera tigris*, Jenny and Schmid 2002; European wildcat, *Felis s. silvestris*, Hartmann-Furter 2000; red fox, *Vulpes vulpes*, Kistler et al. 2009; leopard cat, *Prionailurus bengalensis*, Shepherdson et al. 1993).

In addition to how food is presented, the food item itself may also have impacts on zoo carnivore behaviour. In the zoo, many carnivores are fed diets that contain atypical items such as starch. There is evidence that providing more species-typical diet items to zoo carnivores may improve their welfare. McPhee (2002) reported a decrease in off-exhibit stereotypic behaviour when carnivores were provided carcasses for feeding compared to baseline periods when they were fed more traditional processed diets. Fishing cats (*Prionailurus viverrinus*) that were provided with live fish exhibited previously unobserved hunting behaviours, increased exhibit space use and behavioural diversity, and spent less time sleeping, all indicators of improved welfare (Shepherdson et al. 1993). Beyond carnivores, western lowland gorillas (*Gorilla gorilla gorilla*) that were placed on a low-starch biscuit-free diet had decreased rates of regurgitation and reingestion and hair-plucking compared to periods when on a diet that contained processed food items high in starch (Less et al. 2014).

Space restriction has long been considered a cause of stress in zoo animals (Hediger 1950, 1970) and has been shown to increase stereotypic behaviour (Draper and Bernstein 1963; Levy 1944; Paulk et al. 1977). However, increasing exhibit

size does not always decrease stereotypic behaviour (Goerke et al. 1987; Kaufman et al. 2004; Crockett et al. 1995; Bayne and McCully 1989). It is likely that a species' natural history is an important determinant of how space restriction will affect its behaviour, and Clubb and Mason (2003) found that zoo carnivore stereotypy levels positively correlate with home-range size and daily travel distances. One avenue for managing a restricted space in the zoo, when increasing space is not immediately possible, is to provide animals with a more complex environment. Carlstead et al. (1993a) compared the behaviour of leopard cats (*Felis bengalensis*) when housed in a bare exhibit with behaviour in the same exhibit upgraded to included tree branches, rope, wooden shelves, boxes, natural substrates and visual barriers. In the more complex exhibit, the cats had lower urinary cortisol levels, spent less time pacing, and increased the time they spent exploring their exhibit. Mallapur et al. (2002) similarly found that increased complexity of exhibit space correlated with a lower frequency of stereotypic behaviour in Indian leopards (*Panthera pardus fusca*).

The black-footed cat (*Felis nigripes*) is a small African carnivore that travels between 4.5 and 16 km each night, with home range sizes between 500 and 1500 ha (Olbricht and Sliwa 1997). In addition, black-footed cats have on average 10 prey encounters per 5 hrs of hunting (Sliwa 1994). Black-footed cat ranging behaviour, combined with frequent hunting events, suggests that individuals of this species may be highly susceptible to the development of stereotypic behaviour in zoos (Clubb and Mason 2003). At Cleveland Metroparks Zoo (Cleveland, OH, USA) a male black-footed cat exhibited a repetitive locomotor pattern that began in an off-exhibit area and circled the perimeter of the exhibit. In addition, the subject was observed to spend a large portion of his day in an off-exhibit holding area not visible to the public. Given that a variety of factors could be influencing the animal's behaviour, and that no prior species-specific assessments were available, a stepwise intervention plan was developed to address three common causes of stress in carnivores: lack of natural foraging opportunities, a low stimulation environment and the consumption of atypical dietary items. While the focus of this study was on how husbandry changes affected the subject's repetitive locomotor behaviour and time spent not visible, additional behaviours were also assessed to examine any wider impacts these changes may have had on the cat.

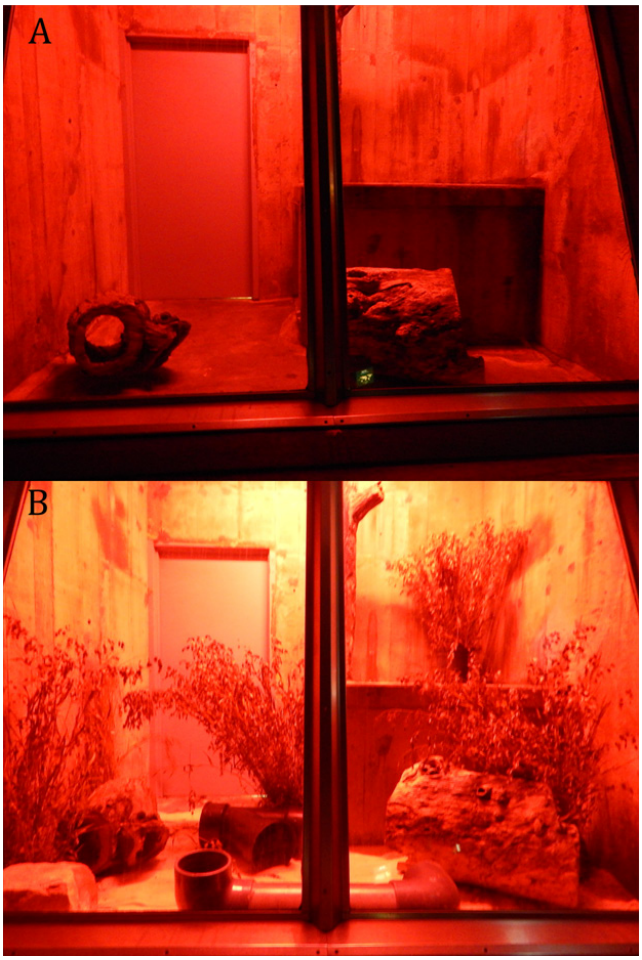

Figure 1. The subject's exhibit prior to (A) and following (B) exhibit modifications. The subject's off exhibit holding space is located underneath the raised concrete platform in the back right corner of the exhibit.

Action

The subject was a six-year old male black-footed cat housed in the Primate, Cat and Aquatics building at Cleveland Metroparks Zoo in a 3.3 m^2 nocturnal exhibit on a 12 h dark/12 h light lighting schedule. The cat was housed in an exhibit composed of a concrete floor and several branches for climbing (Figure 1a). The off-exhibit holding space was built into the exhibit so that the roof provided a second vertical level to the exhibit space. The subject was fed his diet in his off-exhibit holding area and was provided access to this space at all times except during cleaning. The daily diet consisted of 15–20 g of Evo Cat and Kitten Dry Cat Food (Nebraska, USA), 40–60 g of Nebraska brand Premium Feline Diet (Nebraska, USA), and whole mice.

This study was conducted for 10 months from July 2013 to April 2014 and a total of 67.7 hrs of behavioural data were collected. Data were collected at least once per week (average of 3.1 observation days per week and 6.0 observations per week). For days that had multiple observations (average 1.8 observations per day), data were always collected during different one-hour blocks (i.e. 1000–1100, 1100–1200, etc.). Data collection was scheduled to occur evenly between the morning (0800–1200) and afternoon (1200–1500), but due to exhibit cleaning in the morning that was at a variable time each day, 61.6% of observations were conducted in the afternoon and 38.4% were conducted in the morning. Data were collected during 20 min focal observations using an instantaneous point sampling method at 30s intervals. At each point, the behavioural state of the subject was recorded (see ethogram in Table 1). Although the repetitive locomotion described here was similar in some respects to pacing behaviour, during pilot observations this individual displayed greater variability than typically encountered in many carnivores, with bouts often including brief pauses to sniff objects and visually scan the visitor area. As a result of this variability and to maximise interobserver reliability, we chose a conservative approach and scored all locomotor behaviour as "locomotion". All data were collected by AL and JW, and research volunteers trained by AL and JW. Inter-observer reliability was greater than 90%.

Data were collected over four incremental phases. Phase one (10–21 July 2013) was an initial baseline assessment of the subject's behaviour with no manipulation. Phase two (22 July to 2 September 2013) consisted of changing the feeding schedule from a once a day feeding to twice daily random feedings. The subject's daily diet was split into two portions and provided randomly, once in the morning between 0800 and 1100, and once in the afternoon/early evening between 1400 and 1730. In phase three (3 September to 2 December 2013), we increased exhibit complexity through the addition of a sand substrate (approximately

Table 1. Ethogram of black-footed cat behaviour.

Behaviour	*Definition*
Investigate	Subject is sniffing substrate, object or food from a close distance (< 6 inches) or pawing at substrate.
Object-directed	Subject is manipulating object, including chewing, licking or pawing.
Self-directed	Subject scratches self or self grooms.
Locomote	Subject is moving with head elevated and includes normal walking, repetitive movement and carrying objects. Does not include when animal is investigating substrate or manipulating object.
Alert	Subject is not moving, posed in a stiff legged stance, and head/ears are forward facing.
Rest	Subject is stationary in either a seated or laying down position. Eyes may be either open or closed.
Other	Subject is performing a behaviour not described above.
Not visible	Subject was not visible to data collector.

5 cm deep), buried PVC pipes, tall grasses and other plants and branches (Figure 1b). Phase four (3 December 2013 to 9 April 2014) included the implementation of a new diet. The daily portion of Evo Cat and Kitten Dry Cat Food (15–20g; 7–10% carbohydrate content as reported by manufacturer) was removed and replaced with an increased portion of Nebraska Brand Premium Feline Diet (from 40–60g previously, to 75g; 1.4% carbohydrate content as determined by Medallion Labs, Minneapolis, MN, USA). This diet change reduced the amount of starch in the diet and increased the overall diet volume.

Behaviour data were summarised as a percentage of visible time, which was calculated by dividing the total number of scans the subject engaged in each behaviour by the total number of scans he was visible. Time spent not visible was calculated as the total number of scans not visible divided by the total number of scans for that observation. Due to the single subject design of this study, nonparametric Kruskal-Wallis tests were used to test for differences in behaviour across treatments. Significance was set at an alpha of 0.05. Post hoc comparisons were made using Mann-Whitney U tests, with a Bonferroni correction of alpha set at 0.008. Additionally, due to the single subject design, the distribution of the test statistic for each test was determined using the Monte Carlo sampling method with 10,000 permutations (Colegrave et al. 2006). All statistics were run on SPSS (Version 23, Chicago, IL, USA).

Consequences

There was a significant effect of treatment on time spent engaged in locomotion (see Table 2; Figure 2). Locomotion was significantly lower in the low starch diet phase compared to the two previous conditions consisting of the random feeding and exhibit modifications. Although a significant decrease in time spent locomoting was first observed during the implementation of the low starch diet, beginning with the implementation of the random feedings qualitative changes in the subject's repetitive locomotor behaviour were seen. Here the subject began to exhibit novel locomotor behaviours including random, non-repetitive locomotor routes with frequent alert pauses during which he actively scanned his environment. In preliminary observations, similar pauses were observed, but as part of a singular locomotor route. In conjunction with this observed qualitative change in locomotion, a significant change in time spent alert was observed. Alert time was found to significantly increase from baseline following the implementation of the exhibit modifications and the low starch diet. Alert time was also significantly higher after the implementation of the low starch diet and exhibit modifications compared to random feedings. In the wild, black-footed cats frequently encounter prey (Sliwa 1994). Increasing this alert behaviour changed the subject's behaviour to more similarly mirror the behaviour of wild black-footed cats, and also demonstrates an increased engagement with his environment.

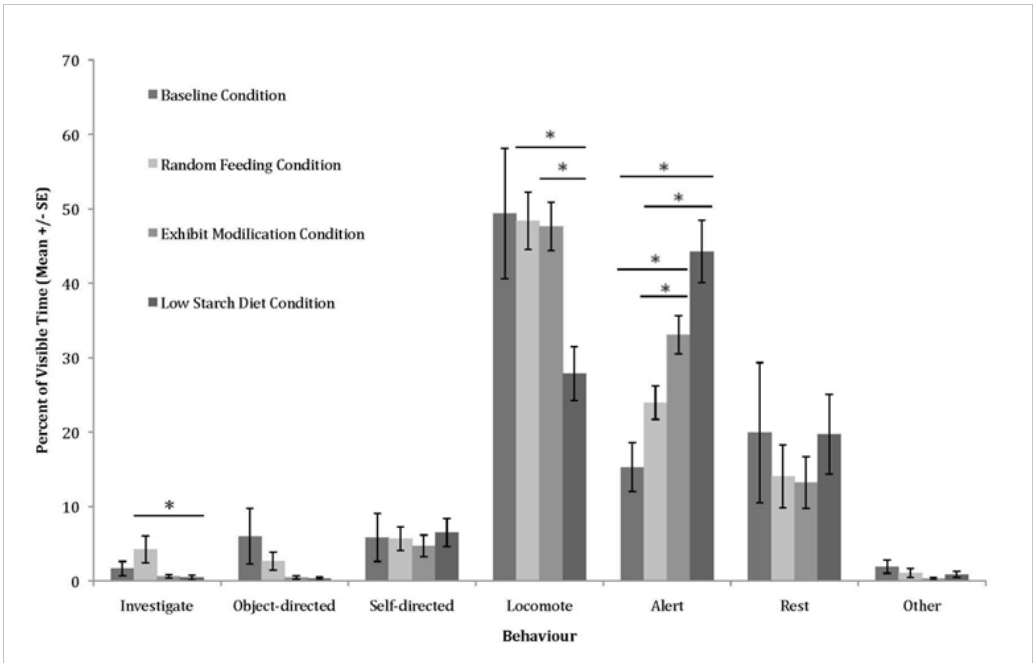

Figure 2. The subject's behaviour as a percent of visible time. Significant post hoc comparisons are denoted by an asterisk.

Table 2. Statistical analysis of time spent engaged in each behaviour across four experimental conditions and all significant *post hoc* comparisons.

				Significant *post hoc* comparisons				
Behaviour	**H**	df	***p***	Condition[b]	U	z	p	***r***
Investigate	11.421	3	0.008[a]	2 to 4	986.0	-2.76	0.005	-0.27
Object-directed	1.936	3	0.619	-	-	-	-	-
Self-directed	8.472	3	0.036[a]	-	-	-	-	-
Locomote	12.064	3	0.007	2 to 4	832.0	-2.91	0.003	-0.29
				3 to 4	972.5	-3.50	0.001	-0.32
Alert	31.540	3	<0.001[a]	1 to 3	384.5	-3.59	<0.001	-0.36
				1 to 4	122.0	-4.37	<0.001	-0.56
				2 to 3	1841.5	-2.76	0.005	-0.23
				2 to 4	637.0	-4.22	<0.001	-0.42
Rest	3.005	3	0.394	-	-	-	-	-
Other	7.404	3	0.055	-	-	-	-	-
Not visible	25.268	3	<0.001[a]	1 to 4	197.5	-3.21	0.002	-0.41
				2 to 3	1780.5	-3.02	0.002	-0.25
				2 to 4	636.0	-4.25	<0.001	-0.42
				3 to 4	1103.5	-2.79	0.005	-0.25

[a]Significant ($p \leq 0.05$). [b]1 = Baseline condition; 2 = Random feeding condition; 3 = Exhibit modification condition; 4 = Low starch diet condition.

The treatment had a significant effect on the subject's time spent investigating. Investigative behaviour significantly decreased in the low starch diet phase compared to the random feeding phase. Although statistically significant, this behaviour accounted for a small portion of the subject's total visible time and probably does not represent a biologically significant change. The decreased frequency in this behaviour correlated with increased time spent on exhibit. This observed difference may be a result of this change. There was also a significant effect of treatment on self-directed behaviour, but post hoc comparisons found no significant difference between individual treatments. There was no significant effect of treatment on object-directed behaviour, rest, or other behaviour.

During the baseline period of this study we observed that the subject spent a large proportion of time not visible in his off-exhibit area. There was a significant effect of treatment on time spent not visible (see Figure 3) following the husbandry changes. Time spent not visible was significantly lower in the low starch diet phase

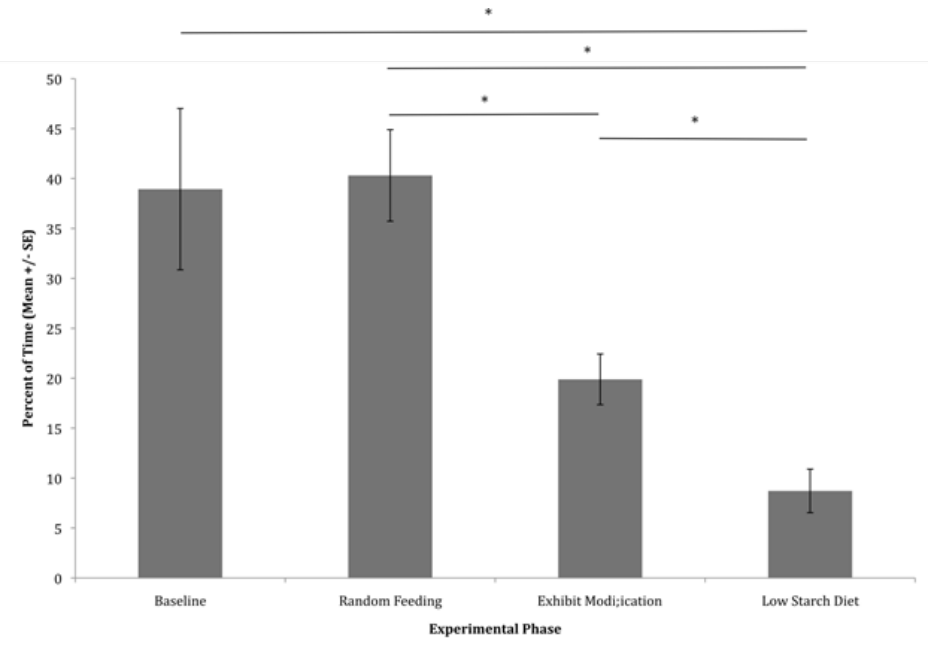

Figure 3. Percentage of time spent not visible. Significant post hoc comparisons are denoted by an asterisk.

compared to baseline, random feeding and exhibit modifications. Time spent not visible was also significantly lower in the exhibit modification phase compared to random feeding phase. Previously, the subject lived in a hardscape exhibit composed of concrete, with off-exhibit space providing the only option for hiding. The exhibit modifications provided a more complex environment with opportunities to hide on exhibit (but still be visible to the public). Black-footed cats are small, nocturnal carnivores that suffer severe predation risk from other carnivores and birds of prey (Olbricht and Sliwa 1997). The inability to properly avoid or hide from potential threats in the zoo environment has been recognised as a potential source of stress for animals in zoos for some time (Hediger 1950, 1970). The inability to properly hide has been shown to increase the stereotypic behaviour of laboratory voles (*Clethrionomys glareolus*, Cooper et al. 1996), gerbils (*Meriones unguiculatus*, Waiblinger and Konig 2004) and mice (Würbel et al. 1998). In laboratory housed domestic cats, time spent hiding was negatively correlated with urinary cortisol levels, demonstrating that the ability to hide is an important mechanism for coping with stress, and an important species-typical behaviour for felines (Carlstead et al. 1993b). Additionally, leopard cats housed in a zoo were found to have decreased rates of pacing when provided with a more complex exhibit that provided multiple opportunities for hiding compared to previously bare exhibits (Carlstead et al. 1993a). The lack of hiding opportunities provided to the black-footed cat in this study may have been a factor contributing to his repetitive locomotor behaviour, and may explain why he spent a large proportion of his time off exhibit.

Stereotypic behaviours can be caused by a variety of factors, and reducing stereotyping may consequently require a multi-step process. In this study we implemented three husbandry changes to reduce the time a male black-footed cat spent engaged in a repetitive locomotor behaviour. We observed qualitative changes in this behaviour after increasing the number of feedings and conducting exhibit modifications, but locomotion was not significantly reduced until the subject was placed on a low starch diet. Hypersinsulinaemia, a higher than expected blood insulin level relative to glucose levels, is associated in humans with greater carbohydrate consumption (Grey and Kipnis 1971), and can cause an increase in dopamine production (Bello and Hajnal 2006). Stereotypic behaviours have been associated with increased stimulation of dopamine neurons (Delfs and Kelley 1990), so it is possible that a reduction in carbohydrates (which are atypical for black-footed cats in the wild) may be a major factor in managing stereotypic behaviour in this species. Further studies are needed to improve our understanding of the effects of low starch diets on zoo animal behaviour, but evidence from this study and a study of gorillas (Less et al. 2014) have demonstrated positive benefits.

This study represents the first empirical evaluation of methods of reducing stereotypic behaviour in a black-footed cat. It should be noted that this study was focused on a single subject and thus the applicability to the wider population of black-footed cats or other small carnivores may be limited. Case studies such as this one can be informative but additional testing with other individuals would certainly be useful. Despite this study's sample size limitation, a stepwise intervention strategy was successfully used to assess how multiple manipulations affected the subject's behaviour, without removing potentially beneficial changes. Overall, we found that husbandry changes that have proven useful in reducing the stereotypic behaviour of other carnivores were also beneficial in this poorly studied species.

Conclusions

1. The implementation of a random feeding schedule, increased exhibit complexity, and a low starch diet decreased the locomotor behaviour of a male black-footed cat and increased the subject's time spent alert within his environment.
2. Increasing exhibit complexity and providing more opportunities for foraging significantly increased the time a male black-footed cat spent on exhibit.

Acknowledgements

The authors would like to thank the research volunteers who helped collect data for this project: Amanda Barabas, Angie Metzger, Joan Rog, Christine Olle, Mike Monson, Renata Wischt, Suzy Peoples and Miranda Berans.

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