

BEHAVIOURAL ADAPTATION OF BRUSHTAIL POSSUMS (*TRICHOSURUS VULPECULA*) TO CAPTIVITY

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Abstract

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Brush-tail possums, Trichosurus vulpecula, are New Zealand's most serious vertebrate pest, facilitating the spread of bovine tuberculosis to livestock, and causing severe damage to native flora and fauna. Possum control has become a national research priority, involving the use of large numbers of captive possums. Successful adaptation of these animals to captivity is important for the welfare of the possums and for the validity of experimental results. The objective of this study was to determine, by behavioural means, the time individually caged possums required for adaptation to captivity. We used a simple behavioural measure – a possum's daily response to a caregiver at feeding (a feeding test) – to assess changes in the behaviour of possums after arrival in captivity. We also recorded changes in possum body weight throughout this period. Initially most possums 'avoided' the caregiver, but within 7 days more than 80 per cent of animals no longer avoided. 'In den' and 'approach' behaviour rapidly increased for the first 14 days in captivity, after which den use became less common as more possums 'approached' the caregiver. By day 29 of captivity, more than 80 per cent of the possums 'approached' the caregiver. The possums' body weight did not change significantly during the first 14 days in captivity, but had increased significantly by day 28, and continued to increase for at least 6 weeks after capture. These data suggest that most possums adapt to captivity within 4 weeks. For the welfare of possums and the reliability of experimental results, we recommend that possums are not used in experiments until at least 4 weeks after capture.

Keywords: *animal welfare, behaviour, brush-tail possum, captivity, Trichosurus vulpecula*

Introduction

Brush-tail possums, *Trichosurus vulpecula*, are Australian marsupials which were introduced to New Zealand in the 1840s to establish a fur trade (Pracy 1974). They are nocturnal, mainly arboreal, opportunistic omnivores, with a mature body weight of 1.4–6.3 kg (Cowan 1990). Possums are considered to be New Zealand's most important vertebrate pest, seriously threatening the livestock industry by facilitating the spread of bovine tuberculosis (caused by *Mycobacterium bovis*) to cattle and deer (Livingstone 1991). They also cause severe damage to (and local extinction of) native plants in forests by selective browsing (Nugent 1995) and, through competition, disturbance and predation, adversely affect native

fauna (Innes 1995). Despite all attempts to control them, possums now occupy more than 90 per cent of the country, occurring at densities up to 20 times that found in Australia (Cowan 1990).

Possum control has become a national research priority, focusing on improving the efficiency and specificity of present control methods, developing alternative control strategies and understanding disease processes in possums. This research has involved a large number of wild possums being captured and housed in captivity, with over 5500 possums used in research during 1996 (Anonymous 1997). Generally, possums used in captive research are wild-caught in box traps shortly before they are required for experimentation. They are then transported to research facilities and housed in small groups in pens or individually in cages. Capture has been shown to be stressful for possums, causing haematological changes and depressing cellular immune responses (Buddle *et al* 1992). The stress of capture, coupled with having to adapt to a new environment, makes possums susceptible to disease and illness. Possums which are stressed in captivity show several clinical signs, including lethargy, poor appetite and diarrhoea. These symptoms may lead to dehydration and weight loss or, in the worst cases, death (Presidente & Correa 1981; Morgan & Peters 1982). Overcrowding and introducing new possums to established groups have been suggested as two major sources of post-capture stress (Presidente 1984). Fear (an animal's negative feeling about its situation) has also been associated with stress in some farmed animals (Broom & Johnson 1993).

The successful adaptation of wild-caught possums to captivity is essential if they are to be used for research purposes. Stress in experimental animals may alter their physiological and behavioural responses, as well as increasing their susceptibility to disease (Griffin 1989). Stress-induced differences in animals' responses may affect the validity of experimental results, so researchers need to be able to determine how long wild-caught animals take to adapt to captivity. Additionally, there may be welfare benefits for the animals if experiments are delayed until they have adapted to captivity. Traditionally, stress assessment has been based on measurements of hypothalamic-pituitary axis (HPA) activity (eg measurement of plasma cortisol concentrations) and other physiological pathways (eg measurement of immunological responses [Manser 1992]). However, more recently, some researchers have regarded stress as both a behavioural and psychological phenomenon, which should be evaluated by a thorough analysis of an animal's behaviour in conjunction with physiological measures (Jansen & Toates 1997).

Several behavioural tests have been developed for measuring stress or fear in animals, including the open-field test and the feeding test. The open-field test has been used reliably to measure emotionality in laboratory rats, by recording their eating and defecating behaviour in an open novel arena (Hall 1934). However, this test has not proven to be a useful indicator of stress in some species (eg foxes [Rekila *et al* 1997]) and has led to the use of the feeding test. The feeding test measures the motivation of a hungry animal to eat in the presence of humans. In this situation, the animal is exposed to a conflict between two competing motivations: hunger and fear (Rekila *et al* 1997). The behaviour of the animal will depend on the balance of these motivations, with the animal avoiding the food if its fear of humans outweighs the motivation to eat.

The objective of this research was to determine whether a simple behavioural measure, the feeding test, could be used to predict when possums housed in cages become adapted to captivity.

Methods

The Ruakura Animal Ethics Committee (Hamilton, New Zealand) approved all procedures, housing and husbandry standards described in this study.

Subjects and housing

Forty-eight wild possums, 22 females and 26 males of a mean (\pm SEM) age of 2.9 ± 0.2 years were trapped in January 1997 using box traps (home-made) in pine forests near Te Puke ($37^{\circ}78'S$, $176^{\circ}33'E$), New Zealand. The animals were transferred from the traps to individual hessian sacks and transported to the Animal Behaviour and Welfare Research Centre (AgResearch Ruakura, New Zealand) where they were weighed and placed in individual wire cages ($550 \times 560 \times 1050$ mm), containing a feed tray, a hanging jute sack for denning, a shelf (300mm from the top of cage) and a water nipple. Each cage was separated by an opaque PVC divider, providing a physical and visual barrier between possums. The possums were fed on a daily diet of wet mash (200g of cereal-based possum pellets [Northern Rolling Mill, Auckland, New Zealand] and water at a 1:1.5 ratio) at 0830h, a single apple at 1400h and water *ad libitum*. The animals were kept on a fixed 12:12h day/night light regime and the temperature in the room was maintained above 10°C. On the day of arrival, each possum was dosed with 5mg ivermectin (Ivomec® pour on; Merck, Sharp & Dohme, Auckland, New Zealand), to remove internal parasites. Four weeks after capture, all possums were anaesthetized with carbon dioxide and oxygen in their sacks (using a mixture of 4l min⁻¹ carbon dioxide: 2l min⁻¹ oxygen). They were aged by tooth wear (Winter 1980) and physically examined for indications of disease during routine veterinary checks. None of the animals were determined to be unwell.

Procedure

An animal caregiver gave each possum an apple in their cage at 1400h daily, using a standard feeding test procedure. The caregiver approached the front of the cage and opened the cage door. An apple was 'offered' (held in the caregiver's outstretched hand at the cage door) to each possum for 30s. If a possum did not respond to the caregiver within 30s the apple was placed on the bottom of the cage. The same animal caregiver offered the apples throughout the experiment. The response of each possum to the caregiver was recorded daily, from the first day in captivity for 37 days. Each type of response that a possum showed was defined (Table 1) and recorded for each animal every day. Changes in the responses of the possums during the apple feeding were then examined.

Table 1 Responses of captive possums towards a caregiver during a 30s daily apple-feeding procedure.

Response	Definition
<i>No response</i>	Possum that is out of the denning sack remains in exactly the same position as it was before the caregiver approached. Does not look at or away from the caregiver.
<i>In den</i>	Possum is in the denning sack when the caregiver approaches and remains in the sack throughout the apple feeding period.
<i>Rear-up</i>	Possum raises its body vertically, sitting on its hindquarters, with both front paws raised to head level when the caregiver approaches. May have mouth open and vocalize.
<i>Avoid</i>	Possum moves part or all of its body away from the caregiver by turning its head away, climbing or jumping away from the cage door or climbing into the denning sack.
<i>Approach</i>	Possum moves part or all of its body towards the caregiver and looks (and may sniff) at the caregiver and apple. Possum may touch the apple or caregiver with its paws or mouth.

The body weight of each possum was recorded at 14-day intervals from the day of arrival. On weighing days, each possum was removed from its cage in its denning sack and placed on the scales. Possum body weight was then calculated by subtracting the predetermined weight of the denning sack from the gross weight measured. The possum was then returned to its cage in the denning sack and not given a feeding test until at least 6h later.

Statistical analysis

We calculated the proportion (and 95 per cent confidence intervals [95% CI]) of possums showing each response type on each day. The first day by which less than 20 per cent (\pm 95% CI) of possums 'avoided', as well as the first day by which at least 80 per cent (\pm 95% CI) of possums 'approached' the caregiver were also determined. The daily probability of 'avoiding' or 'approaching' was modelled for each possum by fitting a polynomial in time on the logit scale, using the generalized linear mixed model (GLMM) procedure in Genstat 5, release 3.1 (Lawes Agricultural Trust, Harpenden, UK). A separate intercept and linear response, plus common quadratic and cubic terms were fitted to the model for each possum. The age and sex of each possum were used as factors in the analysis. The model was then used to estimate the day by which 80 per cent of the possums stopped 'avoiding' for at least 90 per cent of the time, and the day by which 80 per cent of the possums 'approached' for at least 90 per cent of the time. Body weight data was analysed using paired *t*-tests to ascertain differences between values at the time of capture and during the post-capture period.

Results

All the possums in this study remained healthy throughout the experimental period. There were no sex- or age-based differences in their responses. The changes in the possums' responses to the caregiver over time are shown in Figure 1. Most possums initially 'avoided' the caregiver at feeding, but avoidance was observed in less than 20 per cent of the possums by day 7 of captivity (6% avoidance; 95% CI = 1% to 17%). By day 8 of captivity, 80 per cent of the possums did not 'avoid' the caregiver at least 90 per cent of the time. A small number of possums 'reared-up' (< 12%) or showed 'no response' (< 10%) in the first 7 days of captivity, after which time these behaviours were rarely observed. 'In den' and 'approach' behaviour increased throughout the first 14 days in captivity, after which den use became less frequent as more possums came out of their den to 'approach' the caregiver. Nine possums (19%) were never found in their den at feeding time during this experiment. By day 29 after capture, more than 80 per cent of the possums 'approached' the caregiver (92% approach; 95% CI = 80% to 98%). At least 80 per cent of the possums 'approached' the caregiver for at least 90 per cent of the time by day 37 in captivity and every possum 'approached' the caregiver at some time during the experimental period.

Possum body weight did not change significantly during the first 14 days after capture (Figure 2), but had increased significantly by 28 days ($P < 0.001$) and continued to increase further at 42 days after capture ($P < 0.001$). Neither the age nor sex of the possums affected their change in body weight.

Discussion

The behavioural and body weight data collected in this study suggest that individually caged possums in our facility adjusted to captivity within about 4 weeks of capture. These data support the results of previous immune response and haematological studies, which also found that possums adapted within this period (Buddle *et al* 1992).

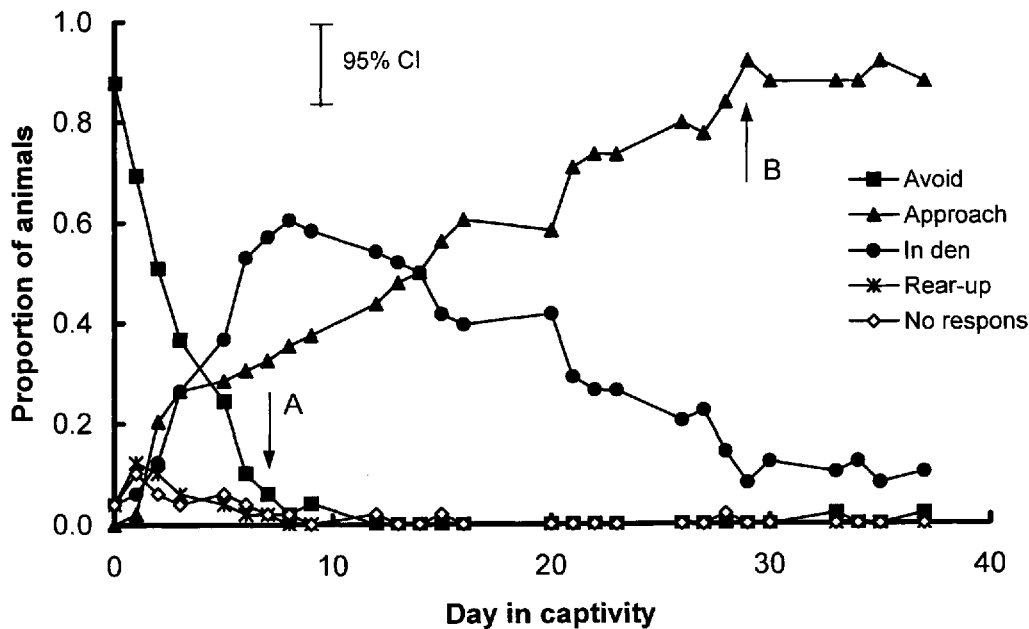


Figure 1 Proportion of possums ($n = 48$) showing each response type after capture. Arrow A indicates the day when over 80 per cent of the possums stopped 'avoiding'; arrow B indicates the day when over 80 per cent of the possums were found to 'approach'. (The 95% confidence interval [CI] shown, represents the largest CI found across all five behavioural categories.)

The behavioural responses of possums changed over the first 4 weeks of captivity. Initially most possums 'avoided' or 'reared-up' at the caregiver during apple feeding, but these responses were quickly replaced by 'in den' or 'approach' behaviour. In many species, avoidance or threat behaviour (such as 'in den' or 'rear-up') is a fear reaction caused by exposure to threatening stimuli (Jones *et al* 1997). The level or duration of fearfulness of an individual may be a basic feature of the animal's temperament, regulated by genetic and environmental factors during development (Boissy 1995). Differences in temperament may account for differences in the adaptive responses of individual animals. Therefore, the variable time taken for individual possums to stop showing a fear response and begin 'approaching' the caregiver in this study, may have depended on the temperament of individual possums. The 'approach' behaviour of possums presumably occurred as a result of possums learning that the caregiver was offering an apple, which is a preferred food. Once a possum became aware that there was a food source available, its motivation to get the food must have outweighed its fear of the caregiver, after which it would 'approach'. Some possums consistently approached within 5–6 days of capture, although it took until day 29 for the majority of possums to have fully adapted to the feeding test. Other researchers have also observed differences in the temperament of possums (McLeod *et al* 1997), with some animals being extremely curious and others always remaining wary of caregivers.

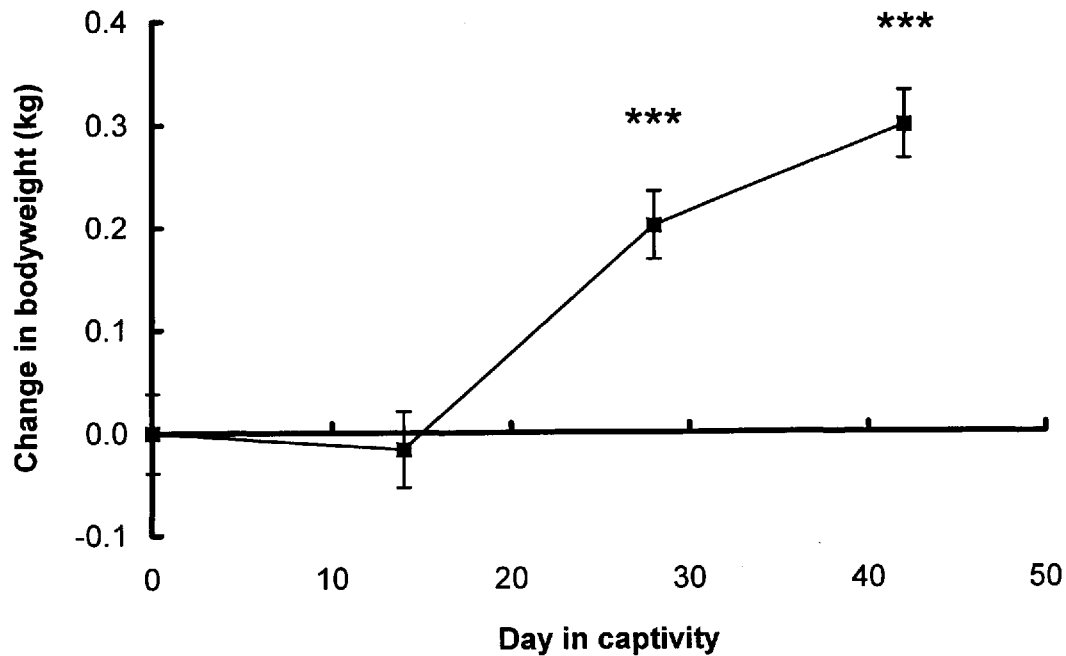


Figure 2 Mean (\pm SEM) body weight changes of possums ($n = 48$) in the period following capture (mean body weight at capture was 2.8 ± 0.2 kg). *** $P < 0.001$.

The feeding test used in this study appeared to be suitable for detecting changes in the fearfulness (and consequent behavioural adaptation) of possums after capture. The data complemented previously collected physiological data and predicted similar patterns of adaptation. Rekila *et al* (1997) found a feeding test to be reliable for measuring fearfulness in farmed blue and silver foxes (*Alopex lagopus* and *Vulpes vulpes*). They also showed that the responses of foxes during the feeding test were stress-related; foxes which did not eat during the feeding test had elevated plasma cortisol levels. While we did not measure cortisol levels in this study, we suggest that possums which avoided the caregiver at feeding were more likely to be stressed than those which approached. Further studies incorporating physiological measures would be required to confirm this. As behavioural measures (such as the feeding test) do not involve animal handling, they may provide less stressful measures of adaptation for newly captured wild animals.

The body weight data we collected showed that most possums did not suffer an extended period of weight loss after capture, and began increasing in weight within 4 weeks. Other researchers have reported similar results (Buddle *et al* 1992). In some colonies, possums which are severely stressed after capture may lose as much as 25 per cent of their body weight (Pearson *et al* 1987). Based on similar body weight data to that observed in this study, McLeod *et al* (1997) suggested that there was no evidence of a period of adaptation after capture of their possums. However, our data show that despite only minor body weight effects, possums did not adapt behaviourally until they had been in captivity for 4 weeks.

Therefore, we would recommend that possums are not used in experimental studies for at least this period.

Animal welfare implications

In experimental studies, it is not always possible to house possums in groups, due to the nature of the experiments being performed. However, wild possums are usually solitary, except in the breeding season, spending little time on active social interaction (Cowan 1990). In addition, the introduction of newly captured possums to groups and associated overcrowding have been major causes of post-capture stress in some possum colonies (Presidente 1984). In this study, we have shown that while individually caged possums initially avoid a caregiver (presumably through fear), they adapt rapidly to housing in individual cages, suffering from no observable long-term behavioural or health effects. Therefore, further research may confirm that the potential for social interaction might not be a major requirement for the welfare of captive possums. The pattern of 'in-den' behaviour shown by possums in this study suggests that possums initially use their dens as an interim coping strategy to avoid contact with a caregiver – and we recommend that dens are always made available to possums. When caged possums are provided with *ad libitum* food and water, a denning sack, an elevated shelf and a visual barrier from other possums, they may be housed successfully in our cages almost indefinitely. The health of the animals at our centre is excellent – and they adapt well to our captive environment. When they are provided with suitable husbandry, the adaptability of possums makes them an excellent research animal with few apparent welfare problems.

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