PERSPECTIVES IN
Animal Health and Welfare
VOLUME 1 / ISSUE 1 / 2022

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https://doi.org/10.34074/piahw.001103

This publication may be cited as:

Cameron, K. E., Bizo, L. A., & Starkey, N. J. (2022). A small-N study of body weight during free-feeding in the brushtail possum (*Trichosurus vulpecula*). *Perspectives in Animal Health and Welfare, 1*(1), 19–27. https://doi.org/10.34074/piahw.001103

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ISSN 2816-0290

A small-N study of body weight during free-feeding in the brushtail possum (*Trichosurus vulpecula*)

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Abstract

Animals in captivity can develop physiological characteristics such as obesity that could negatively affect their health. In the captive brushtail possum (*Trichosurus vulpecula*), it is unknown what effect long-term free-feeding has on body weight. In this study, which took place over 12 months, three possums were fed according to a free-feeding regime. Food intake was measured daily, and the possums were weighed every four days. The possums all gained weight but showed bouts of stable body weights across the year. Stability was evaluated using mathematical models. It was concluded that long-term free-feeding is not recommended for animals-in-waiting for use in operant experiments to mitigate weight gain due to overeating.

Keywords

Brushtail possum, *Trichosurus vulpecula*, free-feeding, captive animals

Background

Captive animals on farms, in zoos and laboratories with relatively small enclosures and barren environments can develop physiological conditions such as obesity that negatively affect their health and welfare (Dawkins, 2004; Rooney et al., 2014). For this reason, laboratory guidelines, such as those for rodents and rabbits, indicate that animals should have enriching environments; that is, housing (and husbandry) that increase natural behaviour and improve animal welfare (National Research Council, 2011; Ratuski & Weary, 2022). Various studies have investigated the use and effects of natural environmental stimulation in laboratory animals such as mice and rats (Ratuski & Weary, 2022), and in zoo animals such as primates (Brent 1995; Nelson & Mandrell, 2005). The latter animals are heavier in captivity than in the wild (Leigh, 1994), due to an abundance of food sources (Swaisgood et al., 2005), or treats given without consideration for nutrition obtained in the daily ration and in enrichment programmes promoting foraging, which are not always measured (Coleman & Novak, 2017; Pierre et al., 2020).

The brushtail possum (*Trichosurus vulpecula*) is a pest species in Aotearoa New Zealand that negatively affects agriculture and indigenous flora and fauna. Pest management is required to kerb the prolific population because of abundant food availability and a lack of predation (Brockerhoff et al., 2010). It is for these reasons that researchers keep captive colonies of possums to investigate their feeding behaviours (Cameron et al., 2013; 2015a; 2016), and psychophysical (Cameron et al., 2015b; Bron et al., 2003) and cognitive abilities (Clarke et al., 2022), as well as methods for eradicating the pest species (McGlone et al., 2014). As a laboratory animal, the possum should receive the same welfare considerations as the typical traditional laboratory rat or mouse (Ator, 2004). However, providing enrichment to the brushtail possum, a large mammal with similar tractability to a feral cat, is difficult in an experimental setting where the dual-purpose cage functions as the home and experimental chamber. The door functions as the operant panel. Stimulation often relies on food variety, a nest box, a possum companion next door (although possums do not live in social groups in the wild and have a dominance hierarchy) (Spurr & Jolly 1999), and an ability to climb from the bottom of the cage to the top of the cage to pull leaves through the holes, albeit a short vertical distance (Signal et al., 2005).

The University of Waikato's Learning, Behaviour and Welfare Research Unit maintained a colony of possums for 20 years. For most of this time, adult possums were used as subjects in operant experiments and kept on food-restricted diets (Signal et al., 2005). It was not known, however, how *ad libitum* food regimes and long-term captivity affect possum body weights and whether seasonal variation in body weight observed in the wild occurs in the laboratory.

A longitudinal field study measuring population health and growth in two locations within the Orongorongo

Valley near Te Whanganui-a-Tara Wellington found seasonal variation in possum body weights (Bell, 1981). Female body weights changed substantially by season, with peak body weights occurring in autumn (Location A) and winter (Location B), with the lowest body weights in winter (with no young) and summer for possums rearing young (Location A), and spring (Location B). This difference was attributed to the variations between the two areas, such as the availability of food (Bell, 1981).

Animals in captivity, such as laboratory or zoo animals, are provided with nutrition appropriate for their species and provided environmental enrichment to allow for behaviours observed in the wild, such as foraging (Newberry, 1995). This has resulted in weight gain in rats (*Rattus norvegicus*) housed in a semi-barren laboratory environment (Johnson et al., 2004), due to overuse of a foraging device and possibly a lack of other stimulation. In addition, zoo animals such as Sclater's lemur (*Eulemur macaco*; physiologically similar in size to the possum), provided with *ad libitum* food as enrichment, rather than encouraged to forage, became lethargic and inactive (Goodchild & Schwitzer, 2008).

The present study used a small number of animals to limit the negative impact of our feed regime on the health and welfare of possums in the colony. To examine the effect of free-feeding on body weight, the food intake and body weights of three captive free-fed brushtail possums were monitored over 12 months. It was expected that the possums would initially gain weight, but show bouts of stable body weight throughout the free-feeding regime and possibly some seasonal variation in their weights.

Method

Three wild-caught brushtail possums (two females, P21 and P22, and one male, P23) aged between 2 and 9 years had been housed in captivity for 2–8 years. Possums were housed in custom-built individual wire-netting cages (540 mm wide x 1050 mm high x 470-mm deep) with a nest box on top and a thick branch from the surrounding forested area to rub and scent mark. The possums also used it to jump and climb up to their nest box. The rooms were in a 12:12 h reversed dark/light cycle beginning at 0930 h. Cleaning and maintenance occurred during the light rotation. The possums had constant access to water. Possums received a minimum of 200 g of each food type: dock (*Rumex obtusifolius*) (placed on top of the cage to be pulled through the bars), apple, and specially made low-calcium possum pellets (Camtech Manufacturing Ltd) in a food tray at 1030 h each day. At 0800 h each morning, any leftover food was weighed. To balance wastage with constant food availability, the daily ration of each food type was then increased if less than 50 g or decreased if more than 100 g was left when the foods were replenished. Ethics approval was obtained from the University of Waikato Animal Ethics Committee (Protocol 865).

Possums were weighed every four days as per Cameron et al. (2014). The procedure involved carrying the possums in a metal carry cage from their home cage to a scale before returning them to their home cage, where they received their daily food ration.

The data was analysed using a mathematical model (Killeen, 1978) and using the methodology from Cameron

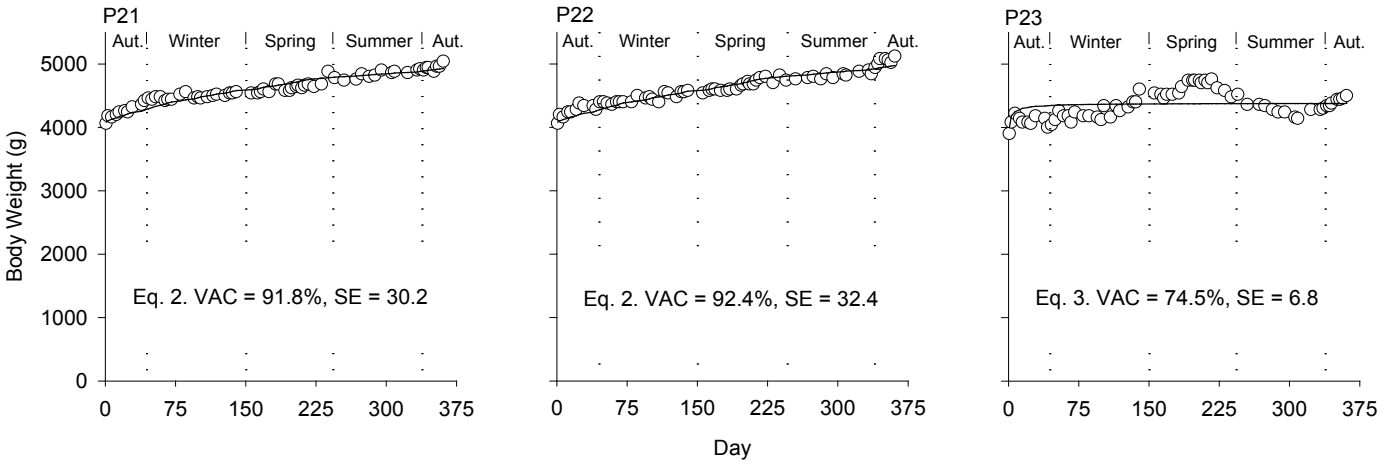

Figure 1. Bodyweight (g) of P21, P22, P23 across days and season (Aut. = Autumn; VAC = variance accounted for; SE = standard error of the mean).

et al. (2014) in which stability was based upon no more than three consecutive increases or decreases in weight within 2.5% of the previous weight. The 5% variation was used because it is a usual increment of the common 85% free-feeding body-weight model (Signal et al., 2005) and because it ensured a sensitive measure to body-weight change.

Result

All three possums gained weight during the 12 months (Figure 1). Food intake fluctuated daily, with average daily difference in food eaten varying across possums: P21 (M = 57.5 g, σ = 52.2 g); P22 (M = 73.3 g, σ = 63.0 g); and P23 (M = 105.4 g, σ = 91.7 g). P23 (the male) had the highest and most varied daily food intake and the greatest fluctuation in body weight.

A mathematical model used to estimate when response-rate curves were stable was applied to the body-weight data to identify when the weights were mathematically stable. The following equations were used to model termination points in the stability of response rates in pigeons (Killeen, 1978). Equation 1 has two parameters (J = number of days and C = a time constant derived by the model that describes rate), R is the predicted body weight and dependent variable, and A is the asymptote or point of stability. Equation 2 includes a parameter where the dependent variable's starting point does not have to be zero. Equation 3 has been used to estimate body weights in possums (Cameron et al., 2014):

$$R = A(1 - e^{-\frac{J}{C}}), \quad (1)$$

$$R = A(1 - e^{-\frac{J}{C}}) + x, \quad (2)$$

$$R = \frac{A.J}{C + J}. \quad (3)$$

Non-linear least squares regression determined the best fits of the equation to the data (see Figure 1). Equation 2 approximated the body weights of P21 and P22 well (VAC = 92.1%). Equations 1 and 3 were poor fits to body weights for P21 and P22 (M = 45.1%, σ =11.2). The derived asymptotes predicted that 99% of body weights would reach a stable value after approximately 299 weighing sessions. Equation 3 approximated the bodyweight of P23 moderately well (the variance accounted for was 74.5%); however, this indicated that stability was reached in 0.5 weigh sessions, which is not accurate looking at Figure 1. Equations 1 and 2 were poor fits to body weights for P23 (M = 23.3%, σ =26.2).

Across weigh sessions, most body weights of P21 and P22 were within 2.5% of the previous weights. This indicates that there were bouts of stability during the 12 months, but overall body weight continued to increase. For P23, there were fewer bouts of stability compared to the other possums, with the most extended bout between 140 and 210 days.

Discussion

The measurement of possum body-weights over 12 months on a free-feeding regime suggests that possums will continue to gain weight with short bouts of stability. There was no indication that the possum body weights in captivity for the two female possums were related to the season, as is previously reported for wild possums (Bell, 1981). The third possum had some variation across seasons, being heaviest in spring. The artificial environment and controlled lighting conditions in the room in which the possums were housed likely attributed to the differences in weight (at least for the male possum) across seasons.

This short communication indicates that long-term captivity under free-feeding leads to weight gain and possibly 'obesity' in laboratory possums. We say this with caution as 'obesity' in possums has not been categorised by a body-weight condition paradigm due to a lack of physiological information, including what 'normal' might look like in a possum. This means that to maintain healthy animals in the laboratory, researchers will need to be aware of the propensity of possums to gain weight on free-feeding regimes long term, especially when housed singly and in small operant cages. Also, keeping animals for future experiments could adversely affect their body weight and possibly health, if being overweight as a possum leads to the same health issues as in dogs and cats, such as diabetes or heart problems (Grazian, 2015); and could present risks to welfare in captive animals where they cannot perform natural behaviour (Dawkins, 2004; Rooney et al., 2014).

Whether eating is likely to function as enrichment or as a source of stimulation in an otherwise impoverished

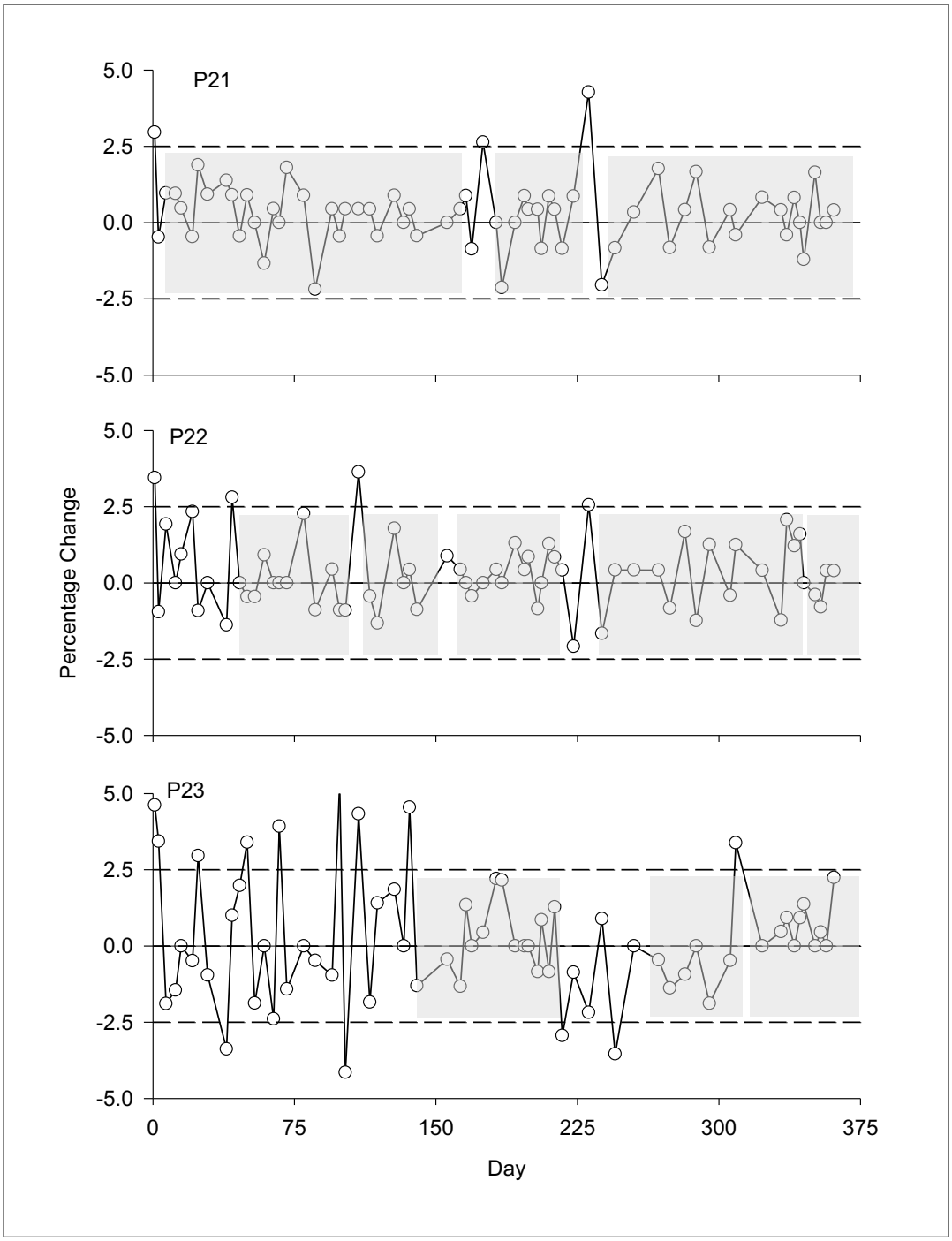

Figure 2. Percentage change in body weight between weigh days. The dashed lines represent ±2.5% change from the previous weight. The grey bands indicate bouts of stability.

environment is presumptuous to propose as the sole factor of increased body weight. Animals in captivity, however, that experience prolonged periods of inactivity (Rooney et al., 20014) and a reduction in environmental complexity, including the need to forage with food easily obtained, gained weight (Brent, 1995; Goodchild & Schwitzer, 2008). Laboratory possums 'in-waiting' should be kept on a restricted diet delivered via an enhanced feeding scheme where animals need to earn food by interacting with a stimulus but also not obtain food too easily. An outdoor colony system would need to be large, to accommodate each possum's need for territory and to ensure foraging and feeding opportunities for all animals (Spurr & Jolly, 1999). Individual systems with a threshold for difficulty would need to be trialled, as possums are opportunistic (Cameron et al., 2013) and will give up if the effort required to obtain food is too great for a food of low value (Cameron et al., 2015, 2016).

In conclusion, long-term free-feeding may put the health of captive possums at risk, as they are likely to

continue to gain weight. Therefore, careful planning and monitoring is needed to balance the nutritional requirement and ability for possums to maintain their health and welfare by performing naturalistic behaviour such as foraging to mitigate instances of overeating and weight gain in captivity or in artificial environments

Acknowledgements

A University of Waikato Doctoral Scholarship supported this research for the first author. The University of Waikato Animal Ethics Committee granted ethics approval for this research (Protocol 865). Address correspondence to Kristie Cameron: kcameron@unitec.ac.nz.

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