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Captive breeding does not alter brain volume in a marsupial over a few generations

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Abstract

Captive breeding followed by re-introduction to the wild is a common component of conservation management plans for various taxa. Unfortunately, captive breeding can result in morphological changes, including brain size decrease. Brain size reduction has been associated with behavioural changes in domestic animals and such changes may negatively influence re-introduction success of captive bred animals. Many marsupials are currently bred in captivity for re-introduction yet the impacts of captive breeding on brain size have never been studied in this taxa. We investigated the impacts of a few generations (2-7) of captive breeding on brain volume in the stripe-faced dunnart (*Sminthopsis macroura*), and found that captive breeding in a relatively enriched environment did not cause any changes in brain volume. Nonetheless, we advocate that great care be taken to provide suitable husbandry conditions and to minimize the number of captive generations if marsupial re-introduction programs are to be successful.

Keywords: Australia; re-introduction; domestication; stripe-faced dunnart; *Sminthopsis macroura*

Introduction

Captive breeding and re-introduction to the wild are major conservation and management techniques for a variety of threatened species (Blamford et al., 1996). Unfortunately, morphological and behavioural changes that may negatively impact on reintroduction success have been associated with captive breeding in various taxa (Kraaijeveld-Smit et al., 2006; Lewis and Thomas, 2001; Moore and Battley, 2006). In domestic species, a significant decrease in brain size (8-34%) compared with their wild ancestors is widespread and is associated with profound changes in behaviour (Kruska, 2005; Stahnke, 1987). Captive breeding has been suggested to correspond to the early stages of domestication and has resulted in a brain size reduction of a similar magnitude in a number of species (e.g. Guay and Iwaniuk, 2008; Röhrs and Ebinger, 1998). This raises the possibility that long-term captive breeding could result in domestication and a loss of wild traits.

Most current captive breeding programs try to minimize the number of generations in captivity to decrease the risk of adaptation to captivity and domestication (McPhee, 2003). Although brain size reduction has been reported over only a few generations in captivity (Runzheimer, 1969), it is not clear how many generations of captive breeding will result in a significant brain size reduction in different species.

Many marsupials are listed as either endangered or critically endangered in Australia and captive breeding has been identified as a major strategy in the conservation and management of some of these species (e.g. Wilson et al., 2003). It is thus very important to determine the effects of captive breeding on the marsupial brain.

Here we investigate the impacts of short term captive breeding (up to 7 generations) on brain size in a small dasyurid marsupial, the stripe-faced dunnart (*Sminthopsis macroura*), to determine the suitability of captive breeding as a source of animals for marsupial reintroductions.

Methods

Stripe-faced dunnart

The stripe-faced dunnart is a small dasyurid marsupial that is found in the semi-arid and arid zones of central and northern Australia (Morton, 1995). Although little is known about the stripe-faced dunnart in the wild, it has been successfully maintained in long-term captive breeding colonies and has been studied extensively in captivity (Au et al., 2010; Menkhorst et al., 2007; Selwood and Woolley, 1991).

Skeletal measurements

We measured 79 dunnart specimens, 43 wild and 36 captive bred. Only sexed specimens with unfractured skulls were considered. For each specimen, we measured endocranial volume using size 12 lead shot (Guay and Iwaniuk, 2008; Iwaniuk, 2001). The skull was filled with lead shot through the foramen magnum. While filling, the skull was repeatedly tapped to ensure good compaction of the shot. Once the cavity was filled, the shot were decanted and weighed to the nearest 0.01g using a digital scale. Measurement error was estimated to be below 1% by repeated measurement (5 times) for a subset of the skulls (n = 38). This is similar to the error reported by others (Iwaniuk, 2001; Marino, 1999). To transform lead shot mass into endocranial volume, we established a calibration curve by measuring the mass of various volumes of shot using a graduated syringe (volume [ml] = 0.1559 X lead shot mass [g]). We also measured skull length (to the nearest 0.1mm using dial callipers).

Captive specimens used in this study had been lodged with Museum Victoria and were derived from a captive colony maintained by Dr. L. Selwood at La Trobe University from 1985 to 2000 (Selwood and Cui, 2006). Animals were kept as described by Woolley (1982) and were provided enrichment via running wheels and play balls in the cages and inclusion of live food (insects) in the diet. For breeding, all animals received a similar treatment irrespective of temperaments and efforts were made to pair females with unrelated or distantly related males. The dunnarts measured died between 1985 and 1992 and had been bred in captivity for 2 to 7 generations.

Statistical analysis

We performed two types of analyses to compare brain volume between captive and wild specimens. 1) We used analysis of variance (ANOVA) to evaluate the effect of captivity and sex on absolute brain volume and 2) we used analysis of covariance (ANCOVA) to evaluate the impact of captivity and sex on brain volume relative to body mass. The latter is necessary to control for potential changes in body size in captivity. As brain size scales allometrically with body mass (Harvey, 1988), we used body mass for our analyses of relative brain volume. Not all specimens had attached body mass data and thus we repeated the analysis using skull length as a proxy for body size. Body mass, skull length and brain volume were $\log_{10}$ transformed before analysis. All statistical analyses were performed using PASW Statistic 18 (SPSS Inc.).

Results

The average brain volume (± SE) of male and female dunnarts was 0.370ml (± 0.007) and 0.355ml (± 0.005) respectively. There was no differences in absolute brain volume between wild and captive specimens ($F_{1, 75} = 0.61$, $P = 0.436$) or between the sexes ($F_{1, 75} = 2.55$, $P = 0.114$). Brain volume was not correlated with body mass, but was highly correlated with skull length (Table 1). The lack of correlation between brain volume and body mass is not unexpected because that correlation is stronger at higher taxonomic levels and is often not significant intraspecifically (Martin and Harvey, 1985; Pagel and Harvey, 1989). There were no effects of captive breeding on brain volume relative to body mass or skull length, but female dunnarts had smaller brains relative to their mass than males (Table 1).

Discussion

Our measurements of stripe-faced dunnart brain volume are similar to those reported by Ashwell (2008). We found no difference in either absolute or relative brain volume between wild dunnarts and dunnarts that had been bred in captivity for a small (2-7) number of generations. In contrast, studies in various taxa discovered a 5-16% brain size reduction in captive bred individuals (Guay and Iwaniuk, 2008; Röhrs and Ebinger, 1998; Runzheimer, 1969). Thus, we expected stripe-faced dunnarts that have been bred in captivity to have smaller brains compared to wild specimens. Although we did not detect any changes in overall brain volume in captive-bred dunnarts, we cannot discount the possibility that various parts of the brain may have been affected by captivity without causing changes in size of the whole brain (e.g.

Bennett, 1976). Alternatively, 7 generations of captive breeding may be insufficient to cause brain size reduction in dunnarts.

Any reduction in brain size and correlated behavioural changes could have important effects on captive bred marsupial reintroduction since, among species, smaller brain size has been associated with lower colonization success in new habitats (Sol et al., 2008). If marsupials show similar traits, brain size reduction could potentially explain poor reintroduction success of captive-bred marsupials (Short et al., 1992).

Various strategies, including decreasing the number of generations in captivity (McPhee, 2003), and equalisation of family size (Allendorf, 1993), have been proposed to mitigate artificial selection in captivity. Providing a captive environment as similar as possible to the natural habitat has also been advocated (Frankham, 2008). Often in a zoo setting, this takes the form of environmental and behavioural enrichment (Newberry, 1995).

Overall, our results demonstrate that, in the case of the stripe-faced dunnart, captive breeding for a small number of generations does not cause brain size reduction. This suggests that captive breeding for reintroduction of marsupial mammals over a small number of generations may be appropriate and may not cause any significant reduction of overall brain size. We suggest that, through various processes including environmental enrichment and low number of captive generation, efforts must be made to ensure that captive breeding does not result in selection for adaptation to captivity as this may reduce the success of breeding colonies and reintroduction programs in marsupials (Williams and Hoffman, 2009).

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Table 1. Results of the ANCOVA analysis of the effects of sex and captivity on brain volume in stripe-faced dunnarts (*Sminthopsis macroura*). Presented are the *F*-ratio and the *P*-value in parenthesis. Values in bold are significant at the $P < 0.05$ level.

	Covariates	
	Body Mass (g)	Skull length (mm)
df	1, 29	1, 71
Captivity	0.28 (0.602)	2.14 (0.148)
Sex	**5.85 (0.022)**	1.08 (0.302)
Captivity x Sex	0.46 (0.504)	0.35 (0.556)
Covariate	0.55 (0.463)	**73.87 (<0.001)**