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SHORT COMMUNICATION



Body mass is not a useful measure of adaptation to captivity in the Orange-bellied Parrot *Neophema chrysogaster*

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ABSTRACT

In captivity, novel selective pressures can lead to divergence from the wild source population, which can be a liability for animals released into the wild. Easily measured indices of change, like body mass, might be important for early detection of adaptation to captivity. We hypothesised that for species subject to long-term captive breeding, body mass may be a useful proxy for detecting morphological adaptations to captivity. We test this (and alternative explanatory variables) with 22 years of pedigree data on Orange-bellied Parrots *Neophema chrysogaster* and predict that adult body mass would change over successive generations in captivity. The best model of adult body mass showed a relationship with maternal effects both directly (heavier mothers produced heavier offspring) and indirectly (different founding maternal lineages produced heavier or lighter descendants), plus circumstances in the year of birth (e.g. years with better food quality produced heavier birds). Body mass did not change with increasing generations of captive breeding. Our results suggest that either adaptation to captivity has not occurred or, if it has, body mass is too coarse an index to detect it. Captive breeding programmes should directly measure traits of interest and ideally compare these to traits of wild birds to identify an ideal morphological baseline.

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Maternal effects; adaptation to captivity; pedigree; captive breeding; endangered species

Introduction

Captive breeding is an important tool for conservation of threatened species. But because captive environments are benign, they relieve natural selective pressures faced in the wild. In captivity, novel selective pressures can act on populations and lead to genetic, behavioural and morphological divergence of captive and wild populations. Adaptation to captivity can be a liability for animals released into the wild. Furthermore, the release of maladapted captive animals can negatively affect key demographic parameters of wild populations (Araki *et al.* 2007, 2009; Willoughby and Christie 2018). Preventing adaptation to captivity is a high priority for captive breeding programmes, and careful genetic management is crucial to this outcome (Frankham 2008). However, despite genetic management, mainly based on pedigrees, some degree of adaptation to captivity may be unavoidable (Chargé *et al.* 2014).

Early detection of adaptation to captivity is critical if captive populations are intended for release to the wild. But morphological changes in captive animals may be difficult to detect if there is no *a priori* reason to suspect a given trait could be undergoing adaptation. Easily measured indices of change might be important for

early detection of adaptation to captivity. If change is detected in the index, this should trigger closer evaluation to identify the underlying trait/s undergoing selection in captivity that could be driving the patterns observed in the index.

Body mass is commonly considered a reasonable index of potential changes arising from adaptation to captivity (O'Regan and Kitchener 2005). Body mass may also be informative about other aspects of life history because it has important implications for individual survival and reproductive success in the wild (Blums *et al.* 2002; Rioux Paquette *et al.* 2014). Furthermore, measurements of body mass are routinely collected in captive breeding programmes and mass is relatively repeatable (Broggi *et al.* 2009), making it a potentially useful proxy if more precise data on other traits are unavailable. However, few bird captive breeding programmes have evaluated the extent of adaptation to captivity. Whether body mass could serve as an index of potential adaptation to captivity has only been considered in very few species (Chargé *et al.* 2014). Adult bird body mass is highly sensitive to a range of extrinsic and intrinsic factors including age (Limmer and Becker 2007), parental investment (Gaston 2003), variation in

food quality during development (Hsu *et al.* 2017) and reproductive (Golet and Irons 1999) and pathological status (Møller *et al.* 1998; Norte *et al.* 2013; Newth *et al.* 2016). To disentangle the impacts of adaptation to captivity from other extrinsic and intrinsic factors, detailed data on individual traits are critical.

We evaluate evidence for adaptation to captivity against other factors that could affect adult body mass of Orange-bellied Parrots *Neophema chrysogaster*. The species may be the rarest parrot in the world, and its migratory wild population declined to only two breeding females in 2016 (Stojanovic *et al.* 2018). Bred in captivity since 1986 (Smales *et al.* 2000), parrots have been released annually since 2013 to augment the surviving wild population (Troy and Kuechler 2018). Given the species has been captive-bred for several generations, it is possible that adaptations to captivity have occurred, which might disadvantage released animals. We use 22 years of data from the largest breeding facility of Orange-bellied Parrots to test the hypothesis that the species has morphologically adapted to captivity, using body mass as an index of change. We had no *a priori* reason to expect either an increase or a decrease in mass, since both directions of change have been recorded in other captive animals (O'Regan and Kitchener 2005), so we instead simply look for evidence of change. We compare alternative explanations of mass variation by testing eight intrinsic and extrinsic factors (including generations of captive breeding) to identify determinants of adult body mass. Based on evidence from other species, if our hypothesis is true, we predict that adaptation to captivity will result in a changing body mass with increasing number of generations of captive breeding.

Methods

We collated data on all individual Orange-bellied Parrots, both alive and dead, hatched at or held within the Tarooma wildlife centre, Tasmania. This is the largest captive breeding facility for the species and is managed by the Tasmanian Government (Department of Environment, Land, Water and Planning 2016). At this facility, changes to animal husbandry practices are confounded with time because they are typically implemented simultaneously for the entire population, so we did not explicitly include aspects of management (e.g. diet) in our analysis.

We used body mass as an index because this data was (i) available for most individuals hatched in captivity, and (ii) we assumed this measure is more likely to be repeatable between observers. Other morphometric data (e.g. wing length or other measures of body size) were

not recorded for most captive-hatched parrots or were collected by multiple staff without quantifying observer error. Data were collated from records collected by keepers over the lifetimes of all individual birds, and we extracted (1) all records of individual body mass; (2) the mean mass of each individual's mother (dam) over her lifetime; (3) the maternal lineage (the identity of the founding wild-hatched dam in the maternal line); (4) the year of birth; (5) the number of offspring produced; (6) the number of generations in captivity; (7) number of maternal generations in captivity; and (8) sex. For variables six and seven, we used the species studbook software PMx (Lacy *et al.* 2012) to calculate values for each individual. We selected these variables because they were available for most individuals in the population, and we excluded individuals from analysis if any of these data were missing. We included the dam's lifetime mean mass to account for different investment in offspring by mothers of varying quality (i.e. non-heritable maternal effects). We included maternal lineage to account for heritable components of body mass and excluded individuals whose parentage was uncertain and those descended from founding mothers that produced fewer than five descendants. Year of birth was included as a proxy for factors that could influence environmental conditions experienced in early life that could result in carry-over effects (Burton and Metcalfe 2014). For example, disease outbreaks in captivity occurred in 2016 (Raidal and Peters 2017; Stojanovic *et al.* 2018), and in 2017, the diet of the captive population was switched from seed to more nutritious pellets. These and other events experienced during the nestling period of captive Orange-bellied Parrots are confounded with year of birth, and thus, we consider this variable a coarse proxy for unmeasured impacts of stochastic events on the population. We excluded the wild-hatched founders of the captive population from our analysis because it is unclear whether the morphological impacts of being hatched in the wild are equivalent to those of individuals that are hatched in captivity.

We used mass as the response variable in a linear mixed model with a normal error distribution, and individual ID was included as a random term to account for repeated measurements from the same birds over their lives. We used stepwise backward selection from a saturated model to derive the most parsimonious model based on $\Delta AIC > 2$. Analyses were undertaken in R version 3.6 (R Development Core Team 2019).

Results

We present data on 374 Orange-bellied Parrots (183 males, 178 females, and 13 unknown) hatched between

Table 1. Models of adult body mass of captive-bred Orange-bellied Parrot ranked by AIC for comparison of each fixed effect against the preferred model (indicated by bold).

Fixed effects	df	AIC	ΔAIC
Founding dam ID + year of birth + mean mass of dam	22	22,766.58	0
Year of birth	13	22,803.67	37.09
Founding dam ID	11	22,819.95	53.37
Mean mass of dam	4	22,837.7	71.12
Null	3	22,854.4	87.82
Sex	5	22,855.83	89.25
Generations in captivity	4	22,856.3	89.72
Maternal generations in captivity	4	22,859.23	92.65
Number of offspring	4	228,60.51	93.93

1994 and 2018. The birds in our sample were the descendants of nine founding mothers and were produced by 94 individual dams. Only 156 birds in our sample bred, producing on average 6.5 fledglings each. There were 4753 records of body mass, and individuals were weighed on average 14 times (range: 1–109) over their lives.

We found no support for the hypothesis that body mass changed with increasing generations in captivity based on the model selection using AIC. We report the AIC values of all single-term models and the preferred model in Table 1 for comparison. The most parsimonious model of adult body mass in captive Orange-bellied Parrots included additive effects of mean dam body mass, maternal lineage, and year of birth (model estimates and confidence intervals are presented in Figure 1).

Discussion

We found no support for our hypothesis that the body mass of Orange-bellied Parrots changed with increasing generations of captive breeding. If morphological adaptation to captivity has occurred in Orange-bellied Parrots, our results suggest that body mass performs poorly as an index for detecting potential changes. However, we did find relationships between body mass and the other variables we measured. Maternal effects and year of birth were the best predictors of adult body mass of captive-bred Orange-bellied Parrots in our sample. Maternal effects were both direct (heavier mothers produced heavier offspring) and indirect (different founding mothers produced heavier or lighter descendants) but were also influenced by circumstances in the year of birth. For example, Orange-bellied Parrots born in 2017 and 2018 were the heaviest individuals recorded in the study, and this corresponds to a change in diet to a higher quality extruded pellet diet in those years. Interestingly, in 2016, when a disease outbreak affected the captive population (Stojanovic

et al. 2018), the mean adult body mass of birds hatched in that year (42.4 g) was not lower than the population mean for other years, but why this is so is unclear. These results are important because they suggest that despite the benign conditions in which the captive population is maintained (*ad libitum* food, protection from predators, prevention of migration), there are still intrinsic and extrinsic factors that affect body mass of adult parrots. Given the importance of adult body mass in fitness and reproductive success of wild birds (Cornioley *et al.* 2017), understanding the factors that influence this trait in captivity may be particularly important if individuals are released to the wild. For example, if lower body mass predicts survival in the wild (Ronget *et al.* 2018), individuals from lightweight maternal lineages or cohorts may be disadvantaged.

Maladaptive morphological changes may result in failure to achieve conservation objectives (e.g. genetic rescue, sex ratio correction) if the survival of captive-bred animals is impaired. Minimising adaptation to captivity is critical if release is the intended purpose of the captive breeding programme. Since the commencement of the Orange-bellied Parrot captive breeding programme, a mean kinship minimisation strategy has been implemented to maintain wild-sourced genetic diversity (Ballou *et al.* 2010) complemented with molecular techniques in more recent years (Hogg, C., unpublished data). These pedigree-based techniques minimise adaptation to captivity (Frankham 2008) so it is perhaps unsurprising that morphological changes would be difficult to detect using a coarse index like body mass. Although body mass has been used to detect adaptation to captivity in other species (O'Regan and Kitchener 2005), this application is less useful in Orange-bellied Parrots. Based on our results, either adaptation to captivity has not occurred or, if it has, body mass is too coarse an index to detect it. Future studies looking for evidence of adaptation to captivity should directly measure traits of interest. For example, (i) dietary differences could drive adaptation of bill shape and gut morphology, (ii) flight in aviaries may affect wing shape, (iii) social isolation may affect song learning, or (iv) floor design (e.g. suspended aviaries) may affect foot/leg morphology. However, these traits may poorly correlate with body mass and thus go undetected. We suggest that the ecology and behaviour of wild species be considered in the context of the captive environment so that traits that are potentially vulnerable to adaptation in captivity can be identified and monitored. Detailed morphological and behavioural data were

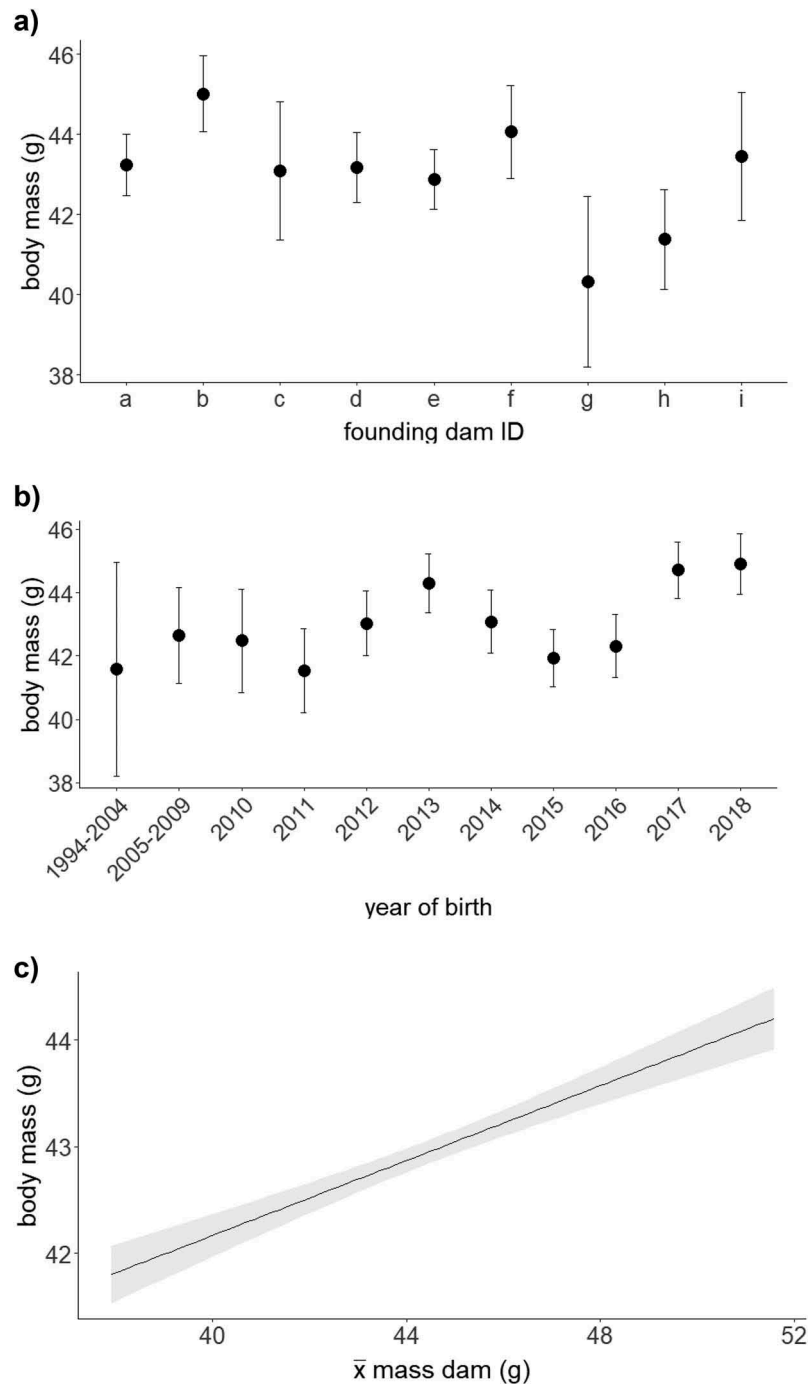


Figure 1. Estimates from the most parsimonious model of adult body mass of captive-bred Orange-bellied Parrots. The figures show relationships between lifetime mean body mass estimates (\pm 95% confidence intervals) of individual birds and their (a) founding dam ID, (b) year of birth, and (c) lifetime mean body mass of their dam.

unavailable for most parrots in our study, and a substantial new effort to collect morphological data may be necessary to identify potential adaptations to captivity. Captive breeding programmes aimed at producing animals for release to the wild should aim to monitor adaptation to captivity. This could be achieved by establishing a database of repeated measures of multiple traits

of interest, for both captive and wild individuals, to identify an ideal morphological baseline. Most captive breeding programmes involve different staff that handle and measure animals over the lifetime of the project. We stress the need to quantify observer error. By keeping a reference set of specimens to estimate measurement error among staff, recovery programmes could ensure that enough data suitable

for analysis might be available for future studies of morphological adaptation to captivity.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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References

- Araki, H., Cooper, B., and Blouin, M. S. (2007). Genetic effects of captive breeding cause a rapid, cumulative fitness decline in the wild. *Science* **318**(5847), 100–103. doi:10.1126/science.1145621
- Araki, H., Cooper, B., and Blouin, M. S. (2009). Carry-over effect of captive breeding reduces reproductive fitness of wild-born descendants in the wild. *Biology Letters* **5**(5), 621–624. doi:10.1098/rsbl.2009.0315
- Ballou, J. D., Lees, C. M., Faust, L. J., Long, S., Lynch, C., Bingham-Lackey, L., and Foose, T. J. (2010). Demographic and genetic management of captive populations. In 'Wild Mammals in Captivity.' (Eds D. G. Kleiman, K. V. Thompson, and C. K. Baer.) pp. 291–252. (University of Chicago: Chicago, London.)
- Blums, P., Clark, R. G., and Mednis, A. (2002). Patterns of reproductive effort and success in birds: Path analyses of long-term data from European ducks. *Journal of Animal Ecology* **71**(2), 280–295. doi:10.1046/j.1365-2656.2002.00598.x
- Broggi, J., Hohtola, E., Koivula, K., Orell, M., and Nilsson, J.-Å. (2009). Long-term repeatability of winter basal metabolic rate and mass in a wild passerine. *Functional Ecology* **23**, 768–773. doi:10.1111/j.1365-2435.2009.01561.x
- Burton, T., and Metcalfe, N. B. (2014). Can environmental conditions experienced in early life influence future generations? *Proceedings of the Royal Society B: Biological Sciences* **281**(1785), 20140311. doi:10.1098/rspb.2014.0311
- Chargé, R., Sorci, G., Saint Jalme, M., Lesobre, L., Hingrat, Y., Lacroix, F., and Teplitsky, C. (2014). Does recognized genetic management in supportive breeding prevent genetic changes in life-history traits? *Evolutionary Applications* **7**(5), 521–532. doi:10.1111/eva.12150
- Cornioley, T., Jenouvrier, S., Börger, L., Weimerskirch, H., and Ozgul, A. (2017). Fathers matter: Male body mass affects life-history traits in a size-dimorphic seabird. *Proceedings of the Royal Society B: Biological Sciences* **284**(1854), 20170397. doi:10.1098/rspb.2017.0397
- Department of Environment, Land, Water and Planning. (2016). National recovery plan for the Orange-bellied Parrot *Neophema chrysogaster*. Canberra.
- Frankham, R. (2008). Genetic adaptation to captivity in species conservation programs. *Molecular Ecology* **17**(1), 325–333. doi:10.1111/mec.2008.17.issue-1
- Gaston, A. J. (2003). Influence of chick mass and date at departure from the colony on adult characteristics in Ancient Murrelets (*Synthliboramphus antiquus*), a precocial seabird. *Auk* **120**(3), 818–826. doi:10.1642/0004-8038(2003)120[0818:IOCMAD]2.0.CO;2
- Golet, G. H., and Irons, D. B. (1999). Raising young reduces body condition and fat stores in Black-legged Kittiwakes. *Oecologia* **120**(4), 530–538. doi:10.1007/s004420050887
- Hsu, B. Y., Dijkstra, C., and Groothuis, T. G. G. (2017). Organizing effects of adverse early-life condition on body mass, compensatory growth and reproduction: Experimental studies in Rock Pigeons. *Journal of Avian Biology* **48**(8), 1166–1176. doi:10.1111/jav.01172
- Lacy, R. C., Ballou, J. D., and Pollak, J. P. (2012). PMx: Software package for demographic and genetic analysis and management of pedigreed populations. *Methods in Ecology and Evolution* **3**(2), 433–437. doi:10.1111/j.2041-210X.2011.00148.x
- Limmer, B., and Becker, P. H. (2007). The relative role of age and experience in determining variation in body mass during the early breeding career of the Common Tern (*Sterna hirundo*). *Behavioral Ecology and Sociobiology* **61**(12), 1885–1896. doi:10.1007/s00265-007-0429-8
- Møller, A. P., Christe, P., Erritzøe, J., and Mavarez, J. (1998). Condition, disease and immune defence. *Oikos* **83**(2), 301–306. doi:10.2307/3546841
- Newth, J. L., Rees, E. C., Cromie, R. L., McDonald, R. A., Bearhop, S., Pain, D. J., Norton, G. J., et al. (2016). Widespread exposure to lead affects the body condition of free-living Whooper Swans *Cygnus cygnus* wintering in Britain. *Environmental Pollution* **209**, 60–67. doi:10.1016/j.envpol.2015.11.007
- Norte, A. C., Lobato, D. N. C., Braga, E. M., Antonini, Y., Lacorte, G., Gonçalves, M., Lopes De Carvalho, I., et al. (2013). Do ticks and *Borrelia burgdorferi* s.l. constitute a burden to birds? *Parasitology Research* **112**(5), 1903–1912. doi:10.1007/s00436-013-3343-1
- O'Regan, H. J., and Kitchener, A. C. (2005). The effects of captivity on the morphology of captive, domesticated and feral mammals. *Mammal Review* **35**(3–4), 215–230. doi:10.1111/mam.2005.35.issue-3-4

- R Development Core Team. (2019). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
- Raidal, S. R., and Peters, A. (2017). Psittacine beak and feather disease: Ecology and implications for conservation. *Emu* **118**(1), 80–93. doi:10.1080/01584197.2017.1387029
- Rioux Paquette, S., Pelletier, F., Garant, D., and Bélisle, M. (2014). Severe recent decrease of adult body mass in a declining insectivorous bird population. *Proceedings of the Royal Society B: Biological Sciences* **281**(1786), 20140649. doi:10.1098/rspb.2014.0649
- Ronget, V., Gaillard, J. M., Coulson, T., Garratt, M., Gueyffier, F., Lega, J. C., and Lemaître, J. F. (2018). Causes and consequences of variation in offspring body mass: Meta-analyses in birds and mammals. *Biological Reviews* **93**(1), 1–27. doi:10.1111/brv.12329
- Smales, I., Brown, P., Menkhorst, P., Holdsworth, M., and Holz, P. (2000). Contribution of captive management of Orange-bellied Parrots to the recovery programme for the species in Australia. *International Zoo Yearbook* **37**(1), 171–178. doi:10.1111/j.1748-1090.2000.tb00719.x
- Stojanovic, D., Alves, F., Cook, H., Crates, R., Heinsohn, R., Peters, A., Rayner, L., *et al.* (2018). Further knowledge and urgent action required to save Orange-bellied Parrots from extinction. *Emu - Austral Ornithology* **118**(1), 126–134. doi:10.1080/01584197.2017.1394165
- Troy, S., and Kuechler, A. (2018). Report on the Tasmanian wild population 2017/18. Department of Primary Industries, Water and Environment, Tasmanian Government, Hobart.
- Willoughby, J. R., and Christie, M. R. (2018). Long-term demographic and genetic effects of releasing captive-born individuals into the wild. *Conservation Biology* **33**(1), 377–388. doi:10.1111/cobi.13217