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Searching for an effective pre-release screening tool for translocations: can trap temperament predict behaviour and survival in the wild?

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Abstract

Individuals often respond to threatening situations in consistently different ways and these differences may predict later translocation success. Thus, the ability to easily identify these differences prior to translocation may assist in improving conservation outcomes. We asked whether burrowing bettongs (*Bettongia lesueur*), a marsupial species that has undergone significant decline since the introduction of exotic predators to Australia, responded in consistently different ways to capture in traps, and if so, whether this was related to anti-predator behaviour, ranging behaviour and survival following translocation. Behavioural responses of 40 bettongs were measured and included response to removal from traps (trap docility), latency to leave a trap or bag and escape behaviour upon release. We used flight initiation distance to measure escape behaviour, and distance moved from diurnal refuges during nocturnal foraging to measure ranging behaviour. Survival was measured through radiotracking after release. Behaviours scored during removal from a trap were consistent and repeatable, and formed a behavioural syndrome with anti-predator and ranging behaviour. Less docile bettongs foraged closer to refuges and had longer flight initiation distances. Less docile bettongs were also more likely to survive after release, although the sample size of mortalities was small. Our results suggest that behaviours scored during trapping could be a useful metric for pre-release screening in translocation programs to enhance the chances of individual survival post-release.

Keywords Personality · Anti-predator behaviour · Pre-release screening · Reintroduction · Burrowing bettong · Translocation

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The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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Introduction

Individuals of many species often behave in consistently different ways (Wolf and Weissing 2012) and they can be described as having predictable temperaments or personality (Dingemanse et al. 2010; Réale et al. 2007). Such temperamental differences have fitness consequences (Smith and Blumstein 2008) and are related to a variety of exploratory behaviours and habitat use (Boon et al. 2008; Fucikova et al. 2009), parasite loadings (Boyer et al. 2010), predation rates (Santos et al. 2015), reproductive success (Réale et al. 2009) and dispersal behaviours (Dingemanse et al. 2003). As a result, wildlife managers tasked with reintroducing or translocating individuals have begun to quantify personality variation in a variety of species (e.g. Vancouver Island marmots *Marmota vancouverensis* Blumstein et al. 2006, swift foxes *Vulpes velox* Bremner-Harrison et al. 2004, brush-tail possums *Trichosurus vulpecula* May et al. 2016), with the aim of improving future translocation success.

If consistent behavioural traits can be identified that are easy to measure and related to post-release survival then pre-release screening could be used to select for individuals with specific temperament types, thus increasing the chances of successful establishment post-release (Smith and Blumstein 2012; Watters and Meehan 2007). For example, bold captive-bred swift foxes were less likely to survive following release into a novel environment (Bremner-Harrison et al. 2004). Similarly, wild-caught brushtail possums that showed most fear during handling had higher survival chances post-translocation (May et al. 2016). Importantly, screened behaviours need to be easy to measure and applicable to situations where animals are captured in the wild for immediate release.

For animals that are routinely trapped, a variety of studies have documented consistent differences in individuals' response to trapping and handling (Montiglio et al. 2012; Petelle et al. 2013; Réale et al. 2000). If trap behaviour is consistent within individuals and related to differences in anti-predator behaviour it could be a useful screening tool in translocation programs. For example reintroduced hihi (*Notiomystis cincta*) that called during handling (an easy to measure trait in the field) dispersed farther than non-calling birds after release (Richardson et al. 2016). If thresholds can be developed for easy-to-measure traits, then individuals could be screened at the point of capture prior to translocation, and the threshold used to determine those individuals included in the release cohort. However, thresholds should ideally not exclude too high a proportion of individuals for release because a major characteristic of successful reintroductions is larger release group size (Fischer and Lindenmayer 2000; Wolf et al. 1996).

We asked whether there were consistent differences in how burrowing bettongs (*Bettongia lesueur*) responded to trapping and handling and whether these trapping-elicited behaviours were related to ranging behaviour, anti-predator behaviour and subsequent survival during a translocation program. The burrowing bettong went extinct from mainland Australia following the introduction of the red fox (*Vulpes vulpes*) and feral cat (*Felis catus*) in the 19th century (Woinarski et al. 2014). Although reintroductions of bettongs have been successful to areas on the mainland where foxes and cats were eradicated or excluded using predator-proof fences (Moseby et al. 2011), reintroductions into unbounded release sites have failed due to predation (Bannister et al. 2016). Failed bettong reintroductions were thought to be due in part to prey naivety, where bettongs lacked appropriate responses to avoid predation by foxes and cats due to an absence of evolutionary and ontogenetic exposure to these predators (Atkins et al. 2016; Moseby et al. 2016).

Materials and methods

Study species

Burrowing bettongs are nocturnal, bipedal medium-sized marsupials (1.6 kg) that live communally in burrow systems (Van Dyck and Strahan 2008). Burrowing bettongs dig for some of their food such as roots and tubers, but are also known to eat fungi, leaves, fruit and seeds (Robley et al. 2001). Repeat trapping studies suggest some animals live for at least 3 years (Short and Turner 1999) but a maximum survival age is not well documented. Once widespread across the arid and semi-arid areas of the Australian mainland, the species was known on only three islands off the coast of Western Australia by the early 1960's (Short and Turner 1993). Reintroductions of bettongs from the islands to mainland Australia commenced in 1992 (Short and Turner 2000) and the species has now been successfully reintroduced to three feral-proof fenced areas on the mainland (Moseby et al. 2011). The species is currently listed as near threatened on the IUCN red list (Richards et al. 2008).

Study site

We studied burrowing bettongs at the Arid Recovery Reserve in northern South Australia (− 30.3602, 136.9234). The climate is arid with a long-term average rainfall of 160 mm and unpredictable rainfall patterns. Arid Recovery is a 123 km^2 private conservation reserve, divided into six paddocks surrounded by a 1.8 m high predator-proof fence that excludes feral cats, foxes and rabbits (*Oryctolagus cuniculus*). Feral species have been removed from 60 km^2 (four paddocks) of the reserve. Four nationally threatened species have been reintroduced to the 60 km^2 feral-free area of the reserve, the burrowing bettong, the greater bilby (*Macrotis lagotis*), the western barred bandicoot (*Perameles bougainville*) and the greater stick-nest rat (*Leporillus conditor*). The reserve is comprised of a number of habitats including longitudinal orange sand dunes supporting *Acacia* and *Dodonaea* shrubland, clay interdunal swales with chenopod shrubland and mulga (*Acacia aneura*) sand plains.

Burrowing bettongs were reintroduced to one paddock of the reserve in 1999 and 2000 from Bernier Island and Heirisson Prong in Western Australia. Thirty animals were originally reintroduced and the population has now increased to several thousand individuals and extends across the four feral-free paddocks. Bettongs are protected from mammalian predators such as cats and foxes by the exclusion fence but are still at risk of predation by wedge-tailed eagles (*Aquila audax*) at dawn and dusk and if they emerge during daylight hours from their burrows.

Trap behaviour

We trapped, marked and fitted VHF radio collars (25 g, Sirtrack Ltd.) to 40 burrowing bettongs in one of the feral free paddocks of the Arid Recovery reserve in June 2014. Bettongs were trapped in Sheffield wire cage traps (22 × 22 × 55 cm) with a hessian sack placed over the back half of the trap. Traps were set at bettong warrens located by walking the dunes within the exclosure. Traps were set during the afternoon and baited with a mixture of peanut butter and rolled oats. Traps were then checked 2–4 h after dark as bettongs are nocturnal. Collared bettongs were initially captured at their warrens and then trapped again on two subsequent sessions in August and October 2014. During each trapping session we scored bettongs for four behavioural traits.

Trap docility score

We defined docility as an individual's reactivity to being trapped and handled. This personality trait is commonly used in non-applied studies (Bonnot et al. 2014; Petelle et al. 2013; Réale et al. 2000). During each trapping event we quantified bettong behaviour while we removed them from the trap. We used our extensive experience of trapping and handling bettongs to select a priori behaviours that were clearly indicative of more reactive individuals. We dichotomously scored whether animals moved in the trap (1 = yes, 0 = no), made noise (1 = yes, 0 = no), moved immediately from the trap into a capture bag when the door of the trap was opened (1 = yes, 0 = no) and whether they moved in an agitated manner once they were secured in the bag (1 = yes, 0 = no). We then summed these scores and subtracted from a total possible score of 4 to give a trap docility score where 0 = non-docile and 4 = docile. Each bettong was trapped and scored up to three times at least 1 month apart between June and October 2014. Scorers were trained with non-study animals to consistently approach traps and score bettong behaviour. Scorers worked in pairs and were silent during scoring. When approaching the trap, one observer remained 10 m from the trap, and provided illumination by focusing a weak beam of light on the ground next to the back of the trap. The scorer recorded if any movement occurred by the animal as they approached from 10 to 0 m. The scorer then crouched next to the side of the trap, quietly placed a trap bag over the door of the trap, and then opened the door. The scorer waited 3 s before removing the hessian sack from the back of the trap. Bettongs that moved into the bag before the hessian sack was removed were scored as 1 (moved immediately from trap into capture bag). For bettongs that remained in the trap after hessian removal, the scorer blew (standardised as short, sharp blow) through the trap onto the back of the bettong at 3 s intervals to encourage it to leave the trap. Once in the bag, the bag was tied and then held suspended for 5 s to see if the bettong bounced in the bag once secured.

Latency to leave trap

We recorded the latency (quantified in s) from when the trap door was opened to when each bettong was fully inside the capture bag. The time to leave the trap was calculated using multiples of 3 s because the observer blows were administered at 3 s intervals.

Escape score

After processing, bettongs were released 10 m from their warren of capture. Bettongs were orientated towards the warren and the opening of the bag was pulled down in front of the animal to reveal their head. At 3 s intervals the scorer nudged the back of the bettong to encourage it to leave the bag. Once out of the bag the animal was observed for 20 s. Again, we used our extensive experience of trapping and handling bettongs, to select a priori behaviours that were indicative of individuals displaying escape behaviour. We dichotomously scored whether bettongs left the bag immediately (1 = yes, 0 = no) and emitted an alarm call (1 = called, 0 = no), the movement pattern (hop = 0 or run = 1), and the movement direction (sat in open = 0 or went out of sight/into a warren = 1) to give a maximum score of 4, which we inferred would represent the best escape response from a threatening situation.

Latency to leave bag

We recorded the latency to leave the bag defined as the total time in seconds from when the bettong's head was revealed to when they left the bag.

Ranging and anti-predator behaviour

For 27 of the collared bettongs we also scored flight initiation distance as a measure of anti-predator behaviour and distance foraging from their diurnal refuge as a measure of ranging behaviour. We measured both behaviours for each individual on three separate occasions during the study period. Because bettongs are nocturnal, traditional flight initiation distance protocols (Runyan and Blumstein 2004) for diurnal species could not be used, so we first located radio-collared subjects using telemetry. Once a radio signal was located a single observer with a headlamp approached the bettong at a walking pace of 0.5 m/s until the animal fled and then measured the distance (in m) from the observer to the location from which the bettong fled. Some bettongs remained just ahead of the observer and out of sight (deduced from a continuing waning of the signal on approach); these approaches were recorded as 'never seen'. Because the furthest distance that a bettong could reliably be seen with a headlamp was 35 m we estimated a minimum flight initiation distance of 35 m for these never seen bettongs. For each bettong, we then calculated an average flight initiation distance from the three measurements. At the point where bettongs were first sighted on each flight initiation distance assessment we recorded the coordinates using a GPS. We used this coordinate to calculate the distance they were from their "safe" diurnal warren (located during the day with radio-tracking) using the measuring tool in a geographic information system (ArcGIS version 10.3). We calculated an average ranging distance for each bettong from the three tests.

Survival post-release

After the final capture in October 2014, 25 of the 27 radio-collared bettongs were translocated to one of two other paddocks within the Arid Recovery reserve (5–10 km from their capture location). Assignment was at random and all bettongs were moved with conspecifics from their warren. Both paddocks contained similar habitat features but predator assemblages were different between paddocks. Paddock 1 contained wedge-tailed eagles only whilst Paddock 2 contained wedge-tailed eagles and low densities of feral cats (0.19 cats per square km). Paddock 1 also contained other bettongs, although translocated individuals were moved into an area of unoccupied habitat. Fifteen bettongs were moved to paddock 1 and 10 to paddock 2. Bettongs were radio-tracked each day for the first month after release and then weekly thereafter to determine survival. For the purposes of this study, we examined survival in the first 3 months after release, to avoid confounding effects of senescence on post-release survival.

Statistical analyses

We fitted hierarchical linear models (Raudenbush and Bryk 2002; Woltman et al. 2012) to determine the influence of individual bettong, their sex (male/female) and the observation number (1–3) on each of the four behavioural scores. For each behavioural score, we conducted model selection in two steps. Firstly, we fitted two nested linear models in R version 3.1.6 using the packages lme4 (Bates et al. 2014) and lmerTest (Kuznetsova et al. 2017). In model 1, we tested whether individual bettong explained variation in the behavioural score, by fitting a model with only the random effect of individual. In model 2 we added the fixed effects of sex (male/female) and observation number as a continuous covariate (1–3) to model 1. We used a likelihood ratio test (LRT) to select the best fitting model (1 or 2). LRTs compare two models where one is nested within the other [i.e. all variables are included in both models but one model contains additional variables (the larger model)], and tests the null hypothesis that the residual variance from the smaller model does not differ from the residual variance of the larger model (Crainiceanu and Ruppert 2004). A significant p value (<0.05) from an LRT test indicates that the larger model is a better fit for the data. We also examined the Akaike's Information Criterion (AIC) value of the two models to check that the best fitting model selected by the LRT was also the one with the lowest AIC value.

The second step of model selection was to compare the best fitting model (1 or 2) to a linear model with no random effects, using a likelihood ratio test (LRT) implemented through the R package RLRsim (Scheipl et al. 2008). This step was used to determine whether individual was required to explain variance in the behavioural score or whether fixed effects alone were a better fitting model. In cases where model 1 was selected as the best fit at step 1, model 1 was compared to an intercept only null model (i.e. no fixed effects included) (model 3). In cases where model 2 was selected as the best fitting model at step 1, model 2 was compared to a model with only the fixed effect of sex and observation (i.e. individual bettong removed) (model 4). A significant p-value from the LRT would indicate that a model including the random effect of individual was a better fit than a model with only fixed effects or the intercept only model, thus we could infer that consistent individual differences in bettongs (i.e. an individual bettong behaves consistently across observations, but individuals behave differently to others) explained significant variation in the behaviour score. Normality of model residuals was checked for each behavioural score. To normalise residuals, we $\log_{10}$ transformed latency to leave trap and latency to leave bag and conducted final analyses on these transformed variables.

To calculate the repeatability of each behavioural score for each individual we used one of two methods. Where model 1 was the best fitting model, we calculated the intra-class correlation coefficient (ICC = random variance/random + residual variance), as this is the best estimate of the variation explained by an individual (Nakagawa and Schielzeth 2010). Where the best model contained both random and fixed effects (model 2) we calculated the adjusted repeatability using the method of Nakagawa and Schielzeth (2010) implemented with the rpt.adj function from the rptR package (Stoffel et al. 2017).

For behavioural scores that had significant individual variation and were repeatable (trap docility and latency to leave trap), we fitted linear models in R to investigate whether an individual's average behaviour score could predict their (a) average flight initiation distance or (b) average ranging distance. We fitted separate models for each dependent variable (flight initiation distance or ranging distance) and for each behavioural score as a predictor (trap docility score or latency to leave trap). Sex and body mass were included as covariates in all models and all continuous covariates were standardised to a mean of zero. Each model was fitted with a Gaussian error distribution.

To analyse whether repeatable behavioural scores could predict survival post-release, we fitted a logistic regression model using the glm function in R version 3.3.1 with a binomial error structure and logit link function to test whether survival of bettongs within the first 3 months of release was predicted by the average of their repeatable behavioural score. As there were only 25 observations, we limited the number of fixed effects to three, to avoid over-fitting the models. We also implemented single term deletion tests using the drop 1 function in R to determine if any covariates could be removed from the final model. We included release paddock and body mass at release as covariates to account for the differences in predator assemblages between each paddock and physical variation at release. If single term deletion tests revealed that either of the covariates did not improve the fit of the model (i.e. the fit of the model without the covariate was not significantly better), then they were removed from the final model. All continuous covariates were standardised to a mean of zero.

Results

Consistency in trap behaviour scores

Trap docility and latency to leave the trap were the only trap behaviour measures that were both individually different and repeatable. Model 1 (random effect of individual only) was the best fitting model for both trap docility and latency to leave the trap (Table 1). Individual bettong explained 20% of the variation in trap docility and 22% of the variation in the latency to leave trap (Table 1). Latency to leave the trap ranged from 3 to 33 s and averaged 8.63 s. Trap docility score ranged from 0 to 4 and averaged 2.75. Escape scores ranged from 0 to 4 and averaged 2.58. Model 1 was also the best fitting model for escape score, but individual only explained 12% of the variation in escape score and this model was not a significantly better fit than an intercept only model (Table 1), so variation in escape score was not due to consistent individual differences. Latency to leave the bag on release averaged 2.99 s (range: 1 to 20 s). Model 2 (random effect of individual and fixed effects of sex and observation) was the best fitting model for latency to leave bag, but scores were not repeatable (Table 1). Sex and observation were significant factors in explaining latency to leave the bag, male bettongs took longer to leave the bag than female bettongs (estimate 0.113, SE 0.058, $p=0.027$) and latency to leave the bag decreased over repeated trapping occasions (estimate − 0.079, SE 0.028, $p=0.007$).

Trap behaviour, ranging behaviour, and anti-predator behaviour

There were significant relationships between trap docility and latency to leave trap, and bettong flight behaviour and ranging behaviour. There was a positive relationship between trap docility and ranging behaviour (Table 2, Fig. 1), with more docile bettongs moving further from their warrens. Sex and weight were poor correlates of distance moved from warren. Trap docility did not significantly explain flight initiation distance (Table 2). There was a significant negative relationship between latency to leave trap and flight initiation distance (Table 2, Fig. 1). Bettongs that took longer to leave the trap had shorter flight initiation distances (Table 2, Fig. 1). There was a positive relationship between latency to

Table 1 Model selection results for linear models fitted to four behavioural scores measured for *Bettongia lesueur* during removal from a trap

Behaviour score	Obs, ind	AIC m1	AIC m2	LRT m1, m2	AIC m3	AIC m4	LRT m1, m3 or m2, m4	Repeatability
Trap docility	120, 40	334.41	338.28	$\chi^2=0.12$, df = 2 *p*-value = 0.94	336.81	n/a	$\chi^2=4.39$, df = 1 ***p*-value = 0.01**	ICC = 0.20
Latency to leave trap	120, 40	73.15	74.33	$\chi^2=2.82$, df = 2 *p*-value= 0.25	77.64	n/a	$\chi^2=6.49$, df = 1 ***p*-value = 0.004**	ICC = 0.24
Escape score	120, 40	366.47	369.72	$\chi^2=0.75$, df = 2 *p*-value= 0.69	366.17	n/a	$\chi^2=1.71$, df = 1 p-value = 0.08	ICC = 0.12
Latency to leave bag	99, 33	23.82	13.62	$\chi^2=14.20$, ***p*-value = 0.001**	n/a	13.67	$\chi^2=2.05$, df = 1 p-value = 0.06	R = 0.17 p = 0.08

Result of likelihood ratio test (LRT) between model 1 random effect of individual (ind) and model 2 [ind + fixed effects of sex (male/female) and observation 1–3 (obs)] is shown with significant LRT result (in bold) indicating model 2 is best fitting model. Akaike's Information Criterion value for each model is also shown and the lowest value underlined. Result of likelihood ratio test performed between model 3 (intercept only) and model 1, or model 4 (fixed effects only) and model 2 is shown, with significant LRT result (in bold) indicating model 1 or 2 a better fitting model than model 3 or 4. Intra-class correlation coefficients (ICC) are shown as the estimate of repeatability for scores where model 1 was the best fit and adjusted repeatability estimates (Nakagawa and Schielzeth 2010) for when model 2 was the best fit

Table 2 Results of linear models of fixed effects of sex, body mass and (a) trap docility score or (b) latency to leave trap (seconds) on 1. Average ranging distance (m), 2. Average flight initiation distance (m) of *Bettongia lesueur*

	1. Average distance from warren		2. Average flight initiation distance	
	Estimate (SE)	*p*	Estimate (SE)	*p*
(a)				
Intercept	– 414.26 (487.26)	0.40	17.56 (9.31)	0.07
Trap docility	**381.78 (115.42)**	**0.003**	– 0.33 (2.21)	0.88
Sex (male)	– 104.65 (149.66)	0.49	– 2.82 (2.86)	0.33
Body mass	– 0.01 (0.31)	0.98	– 0.001 (0.01)	0.89
(b)				
Intercept	– 21.17 (495.13)	0.97	**19.07 (7.92)**	**0.02**
Latency to leave trap	**42.01 (16.24)**	**0.02**	**– 0.62 (0.26)**	**0.03**
Sex (male)	– 73.91 (161.15)	0.65	– 3.58 (2.58)	0.18
Body mass	0.17 (0.32)	0.58	0.001 (0.01)	0.82

Significant effects are indicated in bold

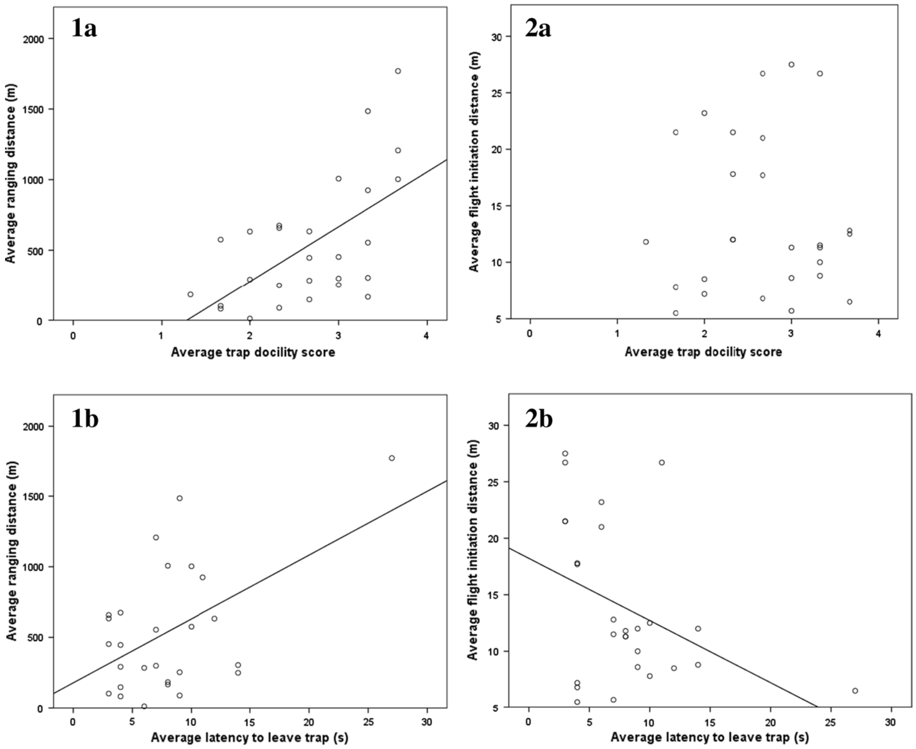

Fig. 1 Relationship between **a** trap docility and **b** latency to leave trap in relation to 1. Average ranging distance, and 2. Average flight initiation distance. Significant relationships are indicated with linear fitted line

leave the trap and ranging distance (Fig. 1). That is, bettongs that took longer to leave the trap moved further from their warrens. Sex and weight were poor correlates of the response variable.

Trap behaviour as a predictor of survival

Our study was primarily designed to quantify individual differences and the correlations between traits; thus, the number of individuals intensively studied was limited. Nevertheless, five of the collared bettongs died within the first 3 months' post-release. The precise cause of death could not be determined due to time lags between death and carcass retrieval. One died in Paddock 1 where wedge-tailed eagles were present, and 4 died in Paddock 2 where a cat and wedge-tailed eagles were present. Because trap docility and latency to leave trap were shown to be significantly different between individual bettongs, and individual bettongs behaved consistently over time (Table 1), we tested whether these behaviour scores could predict survival. We fitted separate models for trap docility and latency to leave the trap.

For trap docility, single term deletion tests indicated that paddock did not significantly improve the model fit so it was removed from the model, and only the fixed effect of body mass was included. There was a trend for trap docility to predict survival, with less docile bettongs being more likely to survive, although this was not significant at $p < 0.05$ (estimate = − 2.336 ± 1.237 SE, $p = 0.059$). As the *p* value was close to < 0.05 we also examined the confidence interval, which did not overlap zero (95% CI = − 5.228, − 0.220), suggesting that less docile bettongs were more likely to survive. In the model with trap docility, body mass was not a significant predictor of survival (estimate = 0.005 ± 0.003 SE, $p = 0.093$, 95% CI = − 0.0002, 0.013). Figure 2 displays the predicted values and their standard errors for the fitted glm model of survival against trap docility and body mass, and suggests that survival probability decreases for bettongs receiving a trap docility score of greater than 2 (Fig. 2). In the model of latency to leave trap, single term deletion tests suggested all covariates should be retained within the model, although none significantly predicted survival (Table 3).

Discussion

Some behaviours that were easily scored while trapping burrowing bettongs were both individually distinctive and repeatable, and these behaviours were correlated with ranging behaviour and antipredator behaviour before translocation. The consistency of these individual responses to the same tests over multiple capture sessions suggests that measures made while an animal is in a trap can be used to reliably assign bettongs along a spectrum of personality types during a single capture event in the wild. We also found that less docile bettongs were more likely to survive, however our sample size was small and should be treated with due caution. Larger sample sizes may have assisted with resolving this further, because the low mortality rates following release did not provide substantial variation to associate measured behavioural traits. Nevertheless, our results suggest that trap behaviour could be a viable index to select individuals that are less docile and that by doing so, survival during subsequent release may be enhanced.

We found that behaviours scored in the trap, namely trap docility and time taken to leave the trap were both consistent within bettongs and varied between individuals. The least

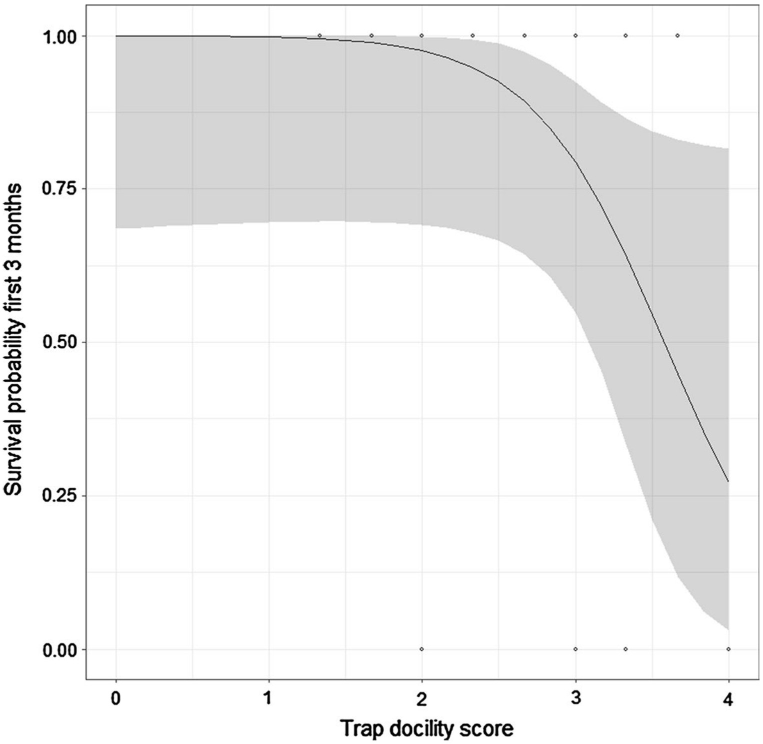

Fig. 2 Predicted survival probability of bettongs 3 months after translocation in relation to trap docility score measured before release

Table 3 Results of logistic regression of survival of bettongs 3 months after translocation in relation to (a) trap docility score and (b) latency to leave trap

	Estimate	Standard error	p	2.5% CI	97.5% CI
(a)					
Intercept	0.509	3.593	0.887	– 6.404	8.368
Trap docility score	– 2.336	1.237	0.059	**– 5.228**	**– 0.220**
Body mass	0.005	0.003	0.093	– 0.0002	0.013
(b)					
Intercept	– 1.046	3.035	0.730	– 7.178	5.181
Latency to leave trap	0.002	0.110	0.988	– 0.206	0.263
Body mass	0.002	0.002	0.500	– 0.003	0.006
Paddock	0.662	1.247	0.596	– 1.588	3.774

For each covariate, the model estimate, standard error, p-value and 2.5 and 97.5% confidence intervals are indicated, significant effects are in bold

docile bettongs (trap docility score of 0) moved whilst in the trap, left the trap and entered the catch bag immediately, made warning noises, and moved around in an agitated fashion once in the capture bag. By comparison, the most docile bettongs (score of 4) sat still in the trap, took longer to leave the trap and were quiet in the trap bag. Trapping and handling behaviour has been shown to be consistent in other species such as yellow-bellied marmots (Petelle et al. 2013), possums (May et al. 2016) and birds (Dingemanse et al. 2003). As per previous studies, the temperament types of bettongs could be classified along a spectrum from docile to bold (Réale et al. 2000). The consistency of individual responses to the same tests over multiple capture sessions suggests measures made while an animal is in the trap can be used to reliably assign bettongs along the spectrum of personality types during a single capture event in the wild or in captivity before release.

Our results show that significant individual differences are related to ranging behaviour and anti-predator behaviours and these variants may have different consequences when animals are introduced into novel environments. We found that trap docility and latency to leave the trap influenced flight response and ranging behaviour (distance moved from warren during nocturnal foraging). Bettongs that were less docile remained closer to their warrens during nightly foraging bouts. Staying close to warrens may be construed as an effective anti-predator strategy in the wild because warrens are used as refuges by bettongs to which they flee when chased by predators. The relationship between distance from refuge and predation risk is documented in European rabbits (*Oryctolagus cunniculus*) that were found to move three times farther from their refuge warrens at sites where predators had been removed in comparison to sites where predators were present (Banks et al. 1999). Distance from burrow has also been used to quantify predation risk in hoary marmots (*Marmota caligata*; Holmes, 1984) and yellow-bellied marmots (Monclús et al. 2015) that run to their burrows when attacked by predators.

Bettongs that were less docile and quickly left the trap were also harder to approach during flight initiation distance tests. Similarly, this increased wariness is likely to be advantageous in predator-rich environments because individuals with quicker flight responses are less likely to be killed by a predator after release. Indeed, flight initiation distance has been shown to increase with predator pressure in all taxa where it was studied (mammals, birds, reptiles, invertebrates, fishes, reviewed in (Cooper and Blumstein 2015), and decreases when animals are isolated from predators on islands (Blumstein and Daniel 2005; Cooper et al. 2014).

Although our sample size was small, less docile bettongs were more likely to survive to 3 months. This is consistent with our behavioural findings which found that less docile individuals fled sooner and foraged closer to warrens, potentially effective anti-predator behaviours. These results suggest that bettongs that scored 2 or less for trap docility would be the better candidates for translocation to areas with predators, because their survival probability is predicted to be higher. This study has shown that trap docility score is a repeatable behaviour which means that it should be possible to assess individual docility at the point of capture. Following assessment in hand, it should be possible to select individuals, based on the docility score, for the release cohort. However, it is important to note that other factors such as sex ratio, demography and health are also factors to be considered when selecting a release cohort, and these may not match the required behavioural type. There may also be additional considerations of cost and logistics in trapping and handling, if large numbers of caught animals cannot be included in a release cohort. In addition, given the small sample size of this study, we would caution the use of this threshold without further testing with larger sample sizes. It is important to note that trap temperament for burrowing bettongs varied along a continuum. It is possible that intermediate personality types (between the extremes of bold and docile) may also confer advantages in particular situations. For example, significant individual differences in activity and aggressiveness in North American red squirrels were correlated with risk-taking behaviour, but intermediate individuals were more likely to stay closest to their dens (Boon et al. 2008). The habitat and predator dynamics at the release site may therefore also significantly influence the behavioural types required for the release cohort.

Developing simple and effective screening tools for improved translocation success is a rapidly expanding field in the area of conservation behaviour. Results to date have shown that variation in personality traits can reliably predict survival and movement in some species (Boon et al. 2008; Bremner-Harrison et al. 2004; Haage et al. 2016). The most effective screening tools will use behaviours that are easy to measure, confer a survival advantage and do not exclude the majority of individuals. Our study suggests that a simple trap behaviour test conducted in the wild at first capture, or before release from captivity, may be an effective screening tool for translocations and can predict aspects of ranging and antipredator behaviour in the wild. To validate the use of trap behaviour as a screening tool in translocations, future studies should aim to compare trap behaviour with post release survival using larger sample sizes.

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