Reintroduction of Bridled Nailtail Wallabies Beyond Fences at Scotia Sanctuary – Phase 1

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Forty male bridled nailtail wallabies *Onychogalea fraenata* were translocated from an on-site captive breeding compound to two release areas beyond the 8000 ha conservation fences at Scotia Sanctuary (far western New South Wales) in late July 2010. We tested the hypothesis that site fidelity (facilitated by spreading soil laden with female bridled nailtail wallaby odour at the release site) would increase survivorship by restricting animals to Scotia where intensive pest animal control has occurred. Two groups of fifteen animals were fitted with radio collars and released at the two areas (odour-added and odour-free) and monitored intensively for three months. Seven of the bridled nailtail wallabies survived this period, 19 died and four remain unaccounted for. Of the 19 that died, three were killed by introduced red foxes *Vulpes vulpes*, two by wedge-tailed eagles *Aquila audax* and one by a dingo/dog *Canis lupus dingo*. Two bridled nailtail wallabies died from pneumonia. The causes of death for the remaining 11 individuals are unknown. Following their release, 13 bridled nailtail wallabies remained on Scotia whilst the other 13 left the sanctuary (excluding the four that were censored). Those individuals that stayed on Scotia had much higher survival (46%) than the dispersers (8%). This result demonstrates the importance of encouraging the released animals to remain within the area that is subject to intensive predator control. The bridled nailtail wallabies were released at two sites: in an attempt to encourage site-philopatry we added soil laden with bridled nailtail wallaby urine and faeces at one of these sites. Males released here tended to travel less far, and had higher survival, than the males released at the 'odour-free' site. We believe the wandering males were searching for mating opportunities. Philopatry may be encouraged and survival increased if females are released with males in future phases of the project. We note that the bridled nailtail wallaby population in Scotia's 8000 ha feral free area, and also in Scotia's captive breeding colony, continued to increase during the initial three months of the translocation.

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KEYWORDS: Australian Wildlife Conservancy, bridled nailtail wallaby, fox predation, introduced predators, *Onychogalea fraenata*, reintroduction, Scotia Sanctuary.

INTRODUCTION

Earth is amidst a conservation crisis with extinction rates thousands of times greater than the background rates (Barnosky, Matzke et al. 2011). Numerous other species are becoming threatened with extinction (Schipper, Chanson et al. 2008). Clearly our current conservation strategies are failing and new and innovative conservation strategies are required (Hayward 2011). Australia has fared no better than elsewhere, and indeed has the ignominy of leading the world in the number of mammalian extinctions over the past 250 years with 22 species considered extinct (Johnson 2006).

Introduced predators were the driver of the initial wave of mammalian extinctions in southern Australia

(Burbidge and McKenzie 1989; Kinnear, Sumner et al. 2002; Short and Smith 1994), and may be responsible for a secondary wave of declines currently affecting tropical Australia (Fitzsimons, Legge et al. 2010; Hayward 2002; Woinarski, Armstrong et al. 2010). The most effective way to protect vulnerable species from the threat of feral predators is to physically separate them. Control of feral animals via poison-baiting has traditionally been used to separate Australian fauna from introduced species (Armstrong 2004; Murray, Poore et al. 2006; Possingham, Jarman et al. 2004), however islands free from these invaders have also been used to great effect (Burbidge 2004; Burbidge, Williams et al. 1997; Dickman, Coles et al. 1992; Short 2009; Short, Bradshaw et al. 1992). Islands have limited potential to save all of Australia's threatened species largely because they provide minimal habitat diversity. Consequently, conservation managers have begun creating 'mainland islands' by fencing large mainland areas, eradicating feral animals from within, and then reintroducing native species (Dickman 2011; Hayward 2012; Hayward, Moseby et al. 2012; Short, Turner et al. 1994).

Scotia Wildlife Sanctuary is a private conservation reserve owned and managed by the Australian Wildlife Conservancy. The management of Scotia aims to improve the ecological health of the sanctuary by maintaining and restoring biodiversity and ecological function, and reducing the extent of threats. This management aim has included constructing a feral-proof fence around 8000 ha of mallee habitats, from which all feral animals except house mice *Mus musculus* have been eradicated. The site represents the largest feral-free area on the Australian mainland. Seven regionally extinct species have been successfully reintroduced into this fenced area, (Finlayson, Vieira et al. 2008; Hayward, Herman et al. 2010; Hayward, Legge et al. 2010). One of the reintroduced species was the bridled nailtail wallaby (BNTW; *Onychogalea fraenata*) and by the end of 2011 Scotia protected over 1500 BNTWs within the 8000 ha fenced area, and a further 500 in a 150 ha captive breeding compound. The Scotia animals thus represent over 70% of the world's entire BNTW population, with the remainder spread between three precarious sites in Queensland.

Following the initial, successful reintroductions, we aimed to expand the fauna restoration programme beyond the fenced areas, by implementing a large-scale intensive poison-baiting programme for introduced species, followed by translocations of selected native species that are most likely to withstand some pressure from feral predators. Of the critical weight range fauna that used to occur in the region and have been reintroduced to the fenced area of Scotia, the BNTW was the best candidate for translocation to the unfenced areas of Scotia because:

- it is at the upper end of the critical weight range of species that have declined since European colonisation of Australia (Burbidge and McKenzie 1989; in fact, males are outside this range). Consequently, the threat to the species from a low density of predators is reduced.
- adults are somewhat vulnerable to foxes (but see point above) which are controlled in the region, but less so to cats. In other words, they are most vulnerable to the feral predator that we are best able to control by poison-baiting.
- the three small remaining populations of BNTW in Queensland all exist outside of fenced areas, although anecdotal evidence suggests that fox control benefits population persistence.

This paper describes the results of Phase 1 of the translocation of BNTW beyond Scotia's conservation fences and assesses these results in light of a set of pre-defined criteria for success (Table 1). Success for the Phase 1 release was previously set at 50% survival of the 30 collared males at the end of first three months

Study site

Scotia Wildlife Sanctuary is a 64,653 ha private conservation reserve situated in far-western New South Wales on the South Australian border between Wentworth and Broken Hill. The BNTW release area was located in the southern area of Scotia (Stage 4; Fig. 1). Release site A was situated near the Tararra homestead, while release site B was further west. Both sites had good quality grass and low shrublands for forage alongside suitable shrubby refuge areas. A water trough was also provided at each site, along with supplementary food which was provided freely for the first month and then at weekly intervals thereafter.

The release area had been subjected to an intense introduced predator control programme for almost one year prior to the BNTW release via the integrated use of M44 toxin delivery devices, standard meat and egg baits laden with 1080, and regional coordination of control activities with adjacent landowners. M44s remained in the environment continuously at 1.5 km spacing and bait heads were checked monthly, while standard baits were placed quarterly and removed after 10 days. Both release sites were within the core baiting area that was defended by M44s (Fig. 1). This was surrounded by a buffer of poison baits that extended onto Nanya (to the north-east of the core) and Belvedere Station (to the east; Fig. 1).

Table 1. Release plan, timing, sex ratio of translocated individuals and criteria for success from the original translocation plan (Herman et al. 2010).

Phase	Timing	Males (collared)	Females (collared)	Criteria for success/continuation
1		40 (30)	0	50% of collared animals survive first three months (continuation).
2	Three months post release	40 (10)	20 (20)	50% of collared animals from the subsequent supplementations survive one month.
3	Four months post release	10 (0)	30 (20)	Collared females observed with pouched young 9 months after release (medium-term success).
4	Five months	0	40 (10)	10% of animals observed will be new recruits 12 months after the initial release. Bridled nailtails persist for the life of the radio collars (3 years).
Ultimate				Self-sustaining population in Scotia and surrounds five years after this translocation. This will be evidence of long-term success.

METHODS

Forty male BNTWs were selected from animals captured in the Captive Breeding Compound at Scotia using soft-sided Bromilow cage traps (Kinnear, Bromilow et al. 1988) baited with Jack Rabbit™ pellets. These males were transported back to Scotia's Cook Laboratory in specially constructed racks on the back of 4WD vehicles that were covered with a tarpaulin to minimise temperature stress. The animals were moved into the lab and hung in bags on similar racks until processing.

Animals were sedated with inhaled isofluorothane, measured, tissue samples were taken and pit tags and radio collars were fitted. The collars were made by Sirtrack and weighed less than 3% of body mass. This process took up to 30 minutes per animal, but generally much less. After processing, the animals recovered in a quiet area of the lab under observation from an AWC staff member. Once all animals had been processed and had fully recovered, they were transported to the release area and released.

Release site A was treated weekly with soil containing odour, urine and faeces of female BNTWs in an experiment to test whether this reduced the distance moved by males from the release site and thereby improved translocation success. Release site B was not treated with odour.

All released animals were visually observed within the first week after their release to ensure the collar was appropriately fitted and that they were in good condition based on mobility, body condition, fur presence and absence of obvious injuries. Thereafter their locations were determined daily via direct observation or triangulation using Locate software (Nams 1990) with error ellipses of less than 1ha used for locations (following Hayward, de Tores et al. 2004). The range of the collars from the ground was approximately 1 – 1.5 km, which meant that animals were undetectable beyond this distance from roads. Distance from the release site was calculated as the straight line distance from the release site to the last location of the animal using ARCGIS (ESRI USA). Aerial telemetry was used to find 'missing' or censored BNTWs. Causes of mortality were deduced from signs on the carcass and collar, and evidence at the site of death (following Augee, Smith et al. 1996; Hayward, de Tores et al. 2005) and from toxicological analyses of tissue samples conducted by Ian Japp (Mildura Veterinarian).

Fox activity was determined using the Catling-Allen index (Allen, Engeman et al. 1996) based on an array of unbaited 1.5m wide sand plots at 1.5 km spacing across tracks throughout the centre of both Stage 3 and 4 of Scotia (Fig.1). We acknowledge the substantial problems with such track based indices (Anderson 2001; MacFarland and Van Deelen 2011; MacKenzie, Nichols et al. 2006) and are moving away from them, however the long-term dataset available has used this method. The BNTW population within the captive breeding compound at Scotia was monitored via total counts during feeding before and after Phase 1 of the reintroduction.

Fig. 1. Bridled nailtail wallaby release areas and fox control regions at Scotia. The release areas are shown as blue circles. BNTW refers to bridled nailtail wallaby, Std to standard meat baits and the other acronyms refer to compass directions.

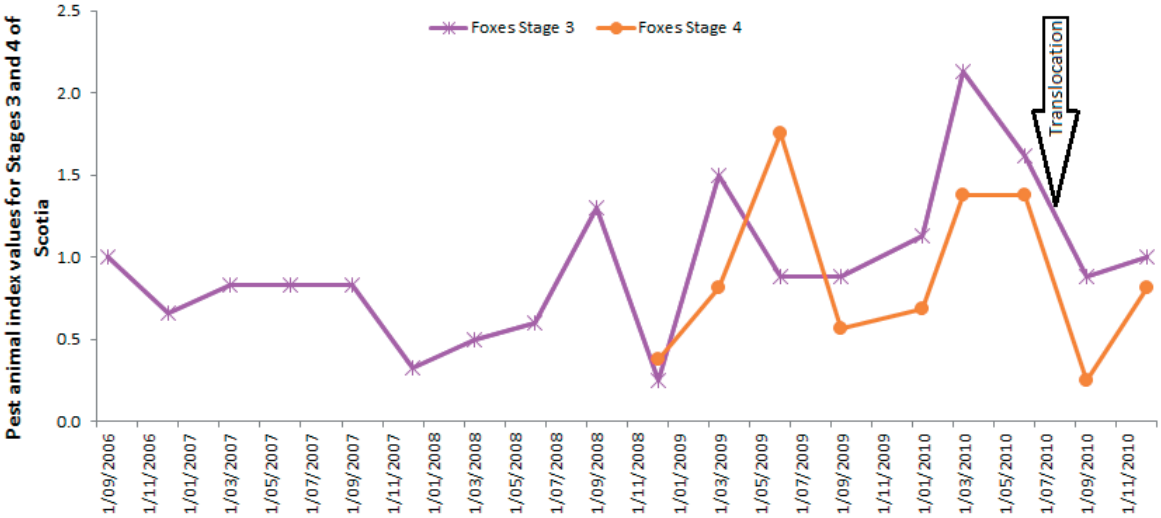

Fig. 2. Index of fox abundance and/or activity at Scotia since 2006 determined using sand plots on tracks via the Catling-Allen index. Stage 4 is the baited release site and Stage 3 is the unbaited control.

Survivorship of released BNTWs was determined by Kaplan-Meier survivorship curves with staggered entry (Pollock, Winterstein et al. 1989). We also used the known fates model in Program MARK with model selection to test the effect of the release method and heterogeneity using Akaike's information criteria and Akaike's weights (*w*) to represent the support for the model (White and Burnham 1999). Estimated known fate survival is presented along with 95%ile confidence intervals. Chi square tests were used to compare the number of animals surviving in the groups living on and off Scotia. Mann-Whitney tests were used to assess the period of time animals survived and t-tests were used to test for differences in the distances that surviving versus non-surviving individuals travelled. Log likelihood (G) tests were used to test whether mortality occurred uniformly throughout the release.

RESULTS

The predator control programme resulted in fox *Vulpes vulpes* index values being very low at the start of the reintroduction programme at the release site (Stage 4) before quickly increasing (Fig. 2). The regional peak in fox index value in spring of 2009 was quickly controlled in the release area (Stage 4) such that only one fox track was recorded throughout this region by early spring 2010 (Fig. 2). This contrasts with the unbaited control region (Stage 3) where the fox index remained high (Fig. 2).

Of the 30 BNTW males that were radio collared, only seven were known to survive to three months, with four more missing and the remainder dead (Fig. 3). Three deaths were attributed to fox predation, one to dingo/dog predation and two more to wedge-tailed eagle predation. Two animals died of pneumonia (based on analysis of lung tissue samples by Ian Japp, Mildura veterinarian), which presented as pus-filled lesions on the lungs of infected animals. The cause of death of 11 individuals was unknown because they travelled into remote areas beyond Scotia's borders and the carcasses were too decomposed to determine a cause of death. Given the majority of these occurred in areas without fox control, foxes seem a likely cause.

Six of the seven surviving BNTW remained on Scotia, while all but one of those that left Scotia died (Fig. 4). There was a significant difference between the locations of the dead and surviving BNTWs with survival being much higher for animals that stayed on Scotia (χ^2 with Yate's correction factor = 6.15, d.f. = 1, $p < 0.05$). Of the set of animals that died, animals that stayed or moved off Scotia survived for similar lengths of time (Mann-Whitney $U = 1.03$, n = 26, p =0.304). Animals that died did not travel significantly further from the release site than those that survived ($t = -1.37$, $d.f. = 228$, $p = 0.169$), however surviving animals continued to travel rather than maintain a territory and their maxima were much larger (33.6 km cf 14.5 km) although this was not significant ($t_{21} = -17.4$, $p = 0.096$).

The majority of mortality events occurred within the first month of the reintroduction (Fig. 5); surviving animals were either warier to begin with, or lost any

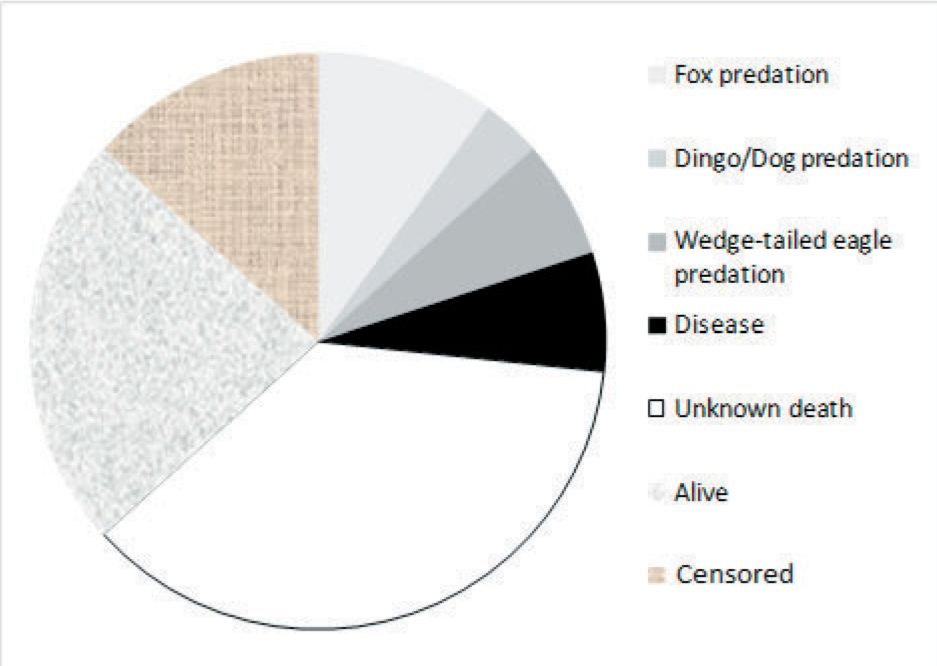

Fig. 3. Fate of the 30 collared reintroduced bridled nailtail wallaby males. 'Censored' refers to individuals that had not been detected for over two weeks.

Fig. 4. Map of the locations of dead and living bridled nailtail wallabies and the cause of their death (where known). Scotia is shown in the pale green, with Nanya Station and other government conservation reserves shown in other shades of green. The conservation fences are shown as the black dashed lines to the north-east of Scotia.

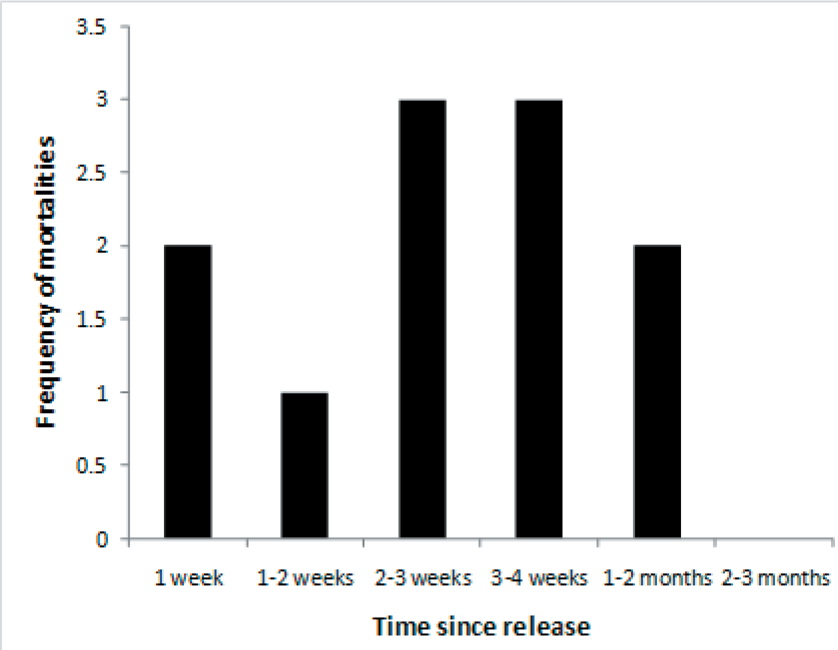

Fig. 5. Survival times of bridled nailtail wallabies after release.

initial naivete reasonably quickly. Animals that died survived an average of 28 days. This rapid mortality rate was significantly different from a uniform mortality rate ($G = 40.5$, d.f. = 5, $p < 0.001$; Fig. 5).

The probability of surviving the three month study period based on the Kaplain-Meier survivorship analysis was 0.29 (Fig. 6). The constant model was the most preferred of the known fates models in Program MARK (S(.) model; AIC_c = 142.505, $w = 0.63$) and it yielded similar survivorship estimates of 0.21 (0.11-0.38) probability of surviving throughout the study period. A second known fates model comparing survivorship between individuals at the two release sites exhibited substantial support (ΔAIC_c = 1.400; w = 0.31) with animals released at the site with odour provisioned surviving better than those released without odour (Odour S = 0.27 (0.11-0.53) cf No Odour S = 0.16 (0.06-0.39)), although the overlapping 95%ile confidence intervals suggest any such differences are marginal. Although there appears to be a large dip in survivorship from late September, this is likely to be spread evenly throughout the study period as additional collars in mortality mode were collected following detection during the aerial telemetry survey. Survivorship curves of animals released at the two sites were significantly different with animals released at sites without female odour present dying at a faster rate than those released at sites where odour was provided (log-rank $G = 83.9$, d.f. = 12, $p < 0.001$).

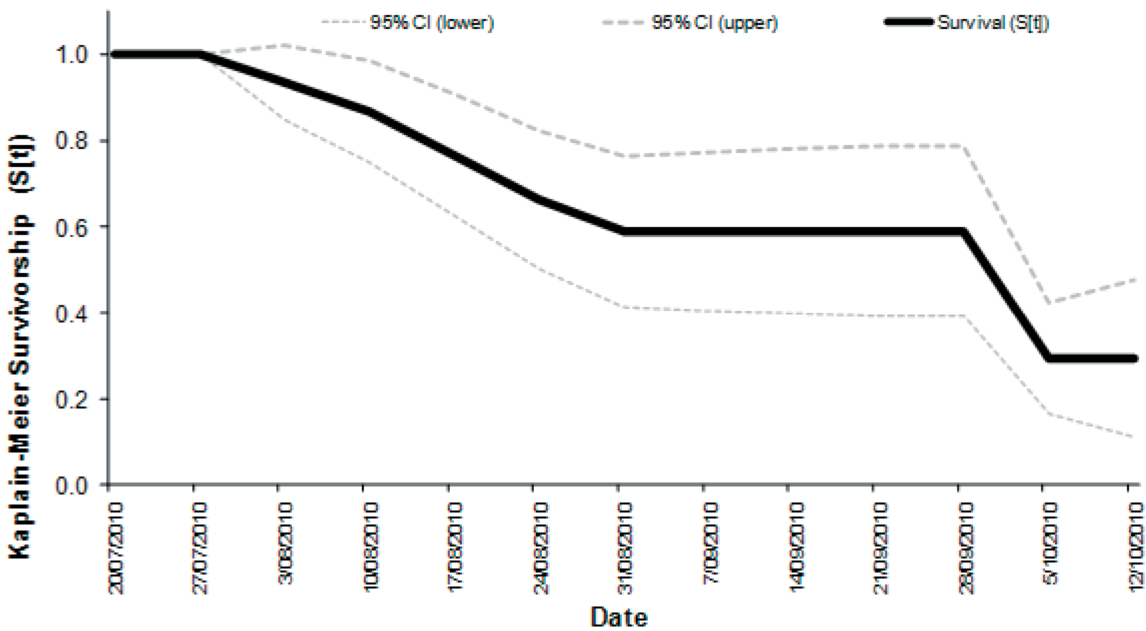

Fig. 6. Kaplain-Meier survivorship values for the 30 male bridled nailtail wallabies released outside fences at Scotia.

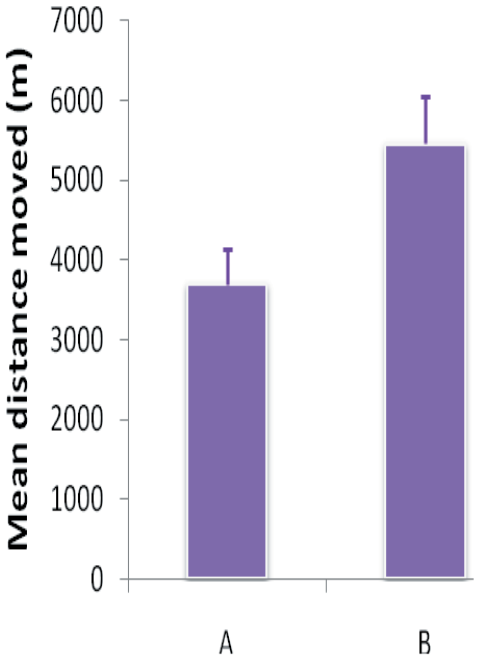

Fig. 7. Mean straight-line distance from the two release sites of released bridled nailtail wallabies at the time of their deaths.

In support of the known fates modelling that found animals from Site A survived marginally better (5 at Site A cf 2 at B), there was a significant difference between the distances moved by animals from the two release sites. Animals released at Site A (odour present) moved shorter distances from the release site (t = -5.59, *d.f.* = 228, $p < 0.001$; Fig. 7). BNTWs released at Site A (odour present) also survived longer than those released at Site B (Site A mean ± 1 S.E. = 56 ± 9 days; Site B = 45 ± 10 days), although the small sample size meant this difference was not significant (Mann-Whitney U = 63.5, n = 26, p = 0.288).

At the time of the Phase 1 release, there were 660 (373-1165) BNTWs in the 8000 ha fenced area at Scotia (based on distance sampling estimates), and at least 468 BNTWs in Scotia's captive breeding compound (based on total counts during feeding). Over the three month study period, and fenced population rose to 729 (503-1066), and the captive population size rose to at least 500, despite the removal of the 40 adult males for the translocation.

DISCUSSION

Of the 30 collared male BNTWs released outside the fences at Scotia, only seven survived the first three months. The majority of deaths occurred off-site: of the 13 BNTWs that remained on Scotia throughout this period, 46% survived. Of the 13 BNTWs that moved off Scotia, only one survived. Alternatively, of seven BNTWs known to be alive at the end of three months, six had remained on Scotia, close to their release site. These results illustrate the importance of retaining the BNTW within the area of intensive predator control on Scotia and the value of intense fox control with a variety of strategies (poison baits plus M44s) over a large regional area (Danggali Conservation Park in South Australia, neighbouring leases in NSW).

Previous modelling suggested that the probability of success of BNTW reintroductions would be increased by using larger founder populations than that used here (McCallum, Timmers et al. 1995). However, we began the programme of translocating BNTWs outside Scotia's fenced area with a small group of males. The first release was partly designed to confirm that the habitats outside the conservation fences at Scotia contained sufficient food resources for BNTWs, whilst minimising impact on the breeding potential of the captive colony (hence males were translocated rather than females). All necropsied BNTWs had full stomachs, full bladders and fat stores around the kidneys, suggesting that the habitat quality outside the fenced area was adequate. Furthermore, the habitats in the release area are no different from those inside the conservation fences where populations of BNTWs have thrived since 2006 (Stage 1) and 2008 (Stage 2).

The BNTW is a strongly sexually dimorphic species with adult males almost twice the body mass of adult females (Fisher 1999). This reflects their polygynous mating system where males compete to mate with as many females as possible. The males selected for translocation were full grown and reproductively active, and this probably explains why they travelled long distances in the weeks following their release – they were most likely searching for mating opportunities. This interpretation is supported by the differences in movements and survival demonstrated between group A (released with female odours) and B (without odour). Furthermore, several animals moved back towards the feral-free fenced area, in which females occurred. Other explanations for the continued expansive movements of the adult males, such as seeking new foraging opportunities, seem unlikely given the abundance of available forage following well above average rainfall during the release.

Wedge-tailed eagles are natural predators of BNTW and they killed two during the three month monitoring period. Given the source population of

BNTWs in the Captive Breeding Compound regularly face this predation risk, it is unlikely that they are naive to eagles. Nonetheless, one of the males that was killed by a wedge-tailed eagle travelled 12 km before stopping beneath an eyrie.

At least two animals died from pneumonia. This could be prevented with prophylactic antibiotic treatment. However, discussions with the veterinarian suggested the costs of such treatment could cause as much harm (through loss of gut bacteria) as no treatment. On veterinary advice, we do not anticipate treating animals in future releases and, indeed, the translocation of associated fauna (e.g. gut parasites of Tasmanian devils *Sarcophilus harrisii*) is now recommended during reintroduction programmes (Burbidge, Byrne et al. 2011).

We used faeces and urine-soaked soil in a trial to encourage male BNTWs to remain close to the release site through thinking females in oestrus may have been present. This approach has been used for other species like black rhinoceros *Diceros bicornis* and African wild dogs *Lycaon pictus* (Borg 2010; Linklater, Flamand et al. 2006). Male BNTWs released at the site with odours tended to remain closer to their release site and survived better. In addition, refreshing the soil more frequently may have enhanced the effect.

Earlier work shows that an annual survivorship of at least 33% is necessary for BNTWs to replace themselves annually (females produce 3 young per year), but much lower is required for replacement over their 6 year lifespan (Fisher 1999). Our three month survivorship is clearly much lower than this annual value. Nonetheless, we propose retaining this threshold in future phases of the translocation programme because of the hypothesised rapid initial decline in translocated animals as they are naïve to local threats before their survivorship improves.

An important lesson from this first release has been that philopatry is critical if animals are to benefit from the protection of the extensive feral predator control programme on Scotia and neighbouring properties. Consequently, the next release of BNTWs at Scotia will include females. Scotia already protects over 70% of the entire population of BNTWs in Australia, and the population trends of the three small sub-populations in Queensland are stable to declining (AWC *unpubl. data*). Expanding the area of occupancy, and thus the population size, of BNTWs at Scotia is critical to the longer-term survival of this species.

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