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Successful reintroduction of red-tailed phascogale to Wadderin Sanctuary in the eastern wheatbelt of Western Australia

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Abstract. Red-tailed phascogales (Phascogale calura) were reintroduced to Wadderin Sanctuary in the eastern wheatbelt of Western Australia in April 2009 with individuals sourced from remnant native vegetation on farmland some 180 km to the west. Their establishment was monitored initially by radio-telemetry and trapping and subsequently by the checking of nest boxes both within and outside the sanctuary. Translocated phascogales established well and bred successfully in their first season. Phascogales remain extant at Wadderin greater than five years post-release and appear to be abundant and to occupy all available habitat. They have spread beyond the fenced sanctuary to adjoining woodland and to shrubland and woodland habitat in a remnant 1.4 kilometres away. Comparison with two other reintroductions of this species (one apparently successful, one not) suggests management and habitat factors that may have contribute to the outcomes.

Additional keywords: translocation, Dasyuridae

Introduction

Reintroduction of endangered fauna is a strategy that has been used widely in Australia, particularly in Western Australia, to improve the conservation status of species and to better understand the impact of various threatening processes on species. Most successful reintroductions of threatened mammals in recent decades have been to sites where introduced predators have been either controlled or eliminated (e.g. Friend and Thomas 1994; Short and Turner 2000; Kinnear et al. 2002; Moseby et al. 2011). Wadderin Sanctuary is a reserve located in the eastern wheatbelt of Western Australia in an area identified as having one of the greatest losses of mammal species of anywhere in Australia (Woinarski and Braithwaite 1990). The reserve was fenced in 2008 to exclude foxes and feral cats with the aim of re-establishing species of vertebrate fauna that had become locally extinct in the eastern wheatbelt.

The former presence of mammal species in the wheatbelt has been detailed by Shortridge (1909: see also Short 2004) and Leake (1962). The red-tailed phascogale (Phascogale calura) was the second of eight species reintroduced to Wadderin Sanctuary, the first being the brushtail possum (Short and Hide 2014).
The red-tailed phascogale is a small, semi-arboreal dasyurid marsupial listed as ‘Endangered’ under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. Its range formerly covered much of semi-arid and arid Australia but it now persists only in the southern Western Australian wheatbelt occupying less than 1% of its former range (Short and Hide 2012), with the core of this remaining range lying between Brookton and Katanning (Fig. 1). Aspects of its ecology and habitat preferences in the Western Australian wheatbelt have been detailed by Kitchener (1981), Bradley (1997) and Short *et al.* (2011). Factors linked to its decline include fragmentation of habitat by clearing for agriculture, particularly of woodland habitats rich in suitable nesting hollows, and predation by feral and domestic cats and by foxes (Short and Hide 2012). Wadderin Sanctuary is in an area of the wheatbelt beyond the contemporary range of the species and where extensive past land clearing has resulted in fragmentation of remaining habitat.

The species’ life history is characterised by a short, synchronized annual mating period in winter followed by the death of all males (Bradley 1997). This reproductive strategy is believed to put the species at risk of reproductive failure in any given year – a possibility believed more likely in arid and semi-arid sites where populations may be sparse or climate unpredictable (Kitchener 1981, Foster *et al.* 2006).

There were no reintroductions of the red-tailed phascogale listed in a recent review of vertebrate translocations within Australia (Short 2009), although there was a trial release of animals undertaken in central Australia in 2006 (Stannard *et al.* 2010) and subsequently a 2010 release of phascogales near Kojonup in the southern wheatbelt of Western Australia (A. Sanders, pers. com.). Soderquist (1994) reported on field trials to examine factors impacting the survival of brush-tailed phascogale (*Phascogale tapoatafa*) reintroduced to Gippsland in Victoria.

The aims of this study were to document the outcome of the reintroduction of red-tailed phascogales to Wadderin Sanctuary, document aspects of their ecology at Wadderin relevant to the outcome, and to compare the outcome with that known for releases of this species elsewhere.

**Methods**

**Study site**

Wadderin (31° 59.2’S, 118° 24.8’E) is a vegetation remnant in the Western Australian wheatbelt approximately 8 km north north-east of Narembeen (Fig. 1) that is largely isolated
by surrounding farmland. The remnant is 560 ha in area, with 430 ha fenced to exclude foxes and feral cats and to form the Wadderin Sanctuary (Fig. 2). The fence, which was completed in early 2008, does not form a barrier to the movement of phascogales. The enclosed area encompasses a series of granite outcrops surrounded by a mix of woodland and shrubland vegetation. Woodlands of jam (*Acacia acuminata*), salmon gum (*Eucalyptus salmonophloia*) and York gum (*E. loxophleba*) make up 245 ha of the area, woodland of rock sheoak (*Allocasuarina huegeliana*) surround the granite outcrops (an additional c. 52 ha), with the balance made up of mallee (*Eucalyptus capillosa* subsp. *polyclada*, *E. eremophila*, *E. rigidula* and other *E.* spp.) and shrubland (*Melaleuca uncinata*, other *M.* spp. and *Allocasuarina campestris*). A substantial part of the area outside the fence includes a vegetation of sparse York gum / jam woodland utilized as a golf course.

The management and history of the sanctuary are described in detail in Short and Hide (2014). Wadderin is within the Shire of Narembeen, where 91.5% of native vegetation has been cleared for agriculture (Safstrom *et al.* 2000). The nearest substantial neighbouring areas of bushland to the sanctuary are the Wadderin railway reserve (175 ha and c. 1.4 km to the east) and Roach Nature Reserve and adjoining bushland (515 ha and 6 km to the west). Wadderin Sanctuary is managed by the local farming community of Narembeen (Short and Stone 2009).

Existing hollows in woodland trees (typically *E. loxophleba* and *E. salmonophloia*) within the sanctuary were supplemented by the addition of 22 nest boxes (c. 450 x 250 x 250 mm with 32 mm diameter entrance hole) placed in trees at a height of 2 – 3 m throughout the sanctuary prior to initial release of phascogale in April 2009. Boxes were partly filled with wool for insulation and nesting. Small entrance holes were designed to exclude nest competitors such as parrots. These boxes were later supplemented by a further 13: six placed in adjoining bushland beyond the fenced area in November 2010; three in the Wadderin railway reserve (with a vegetation predominantly of *Allocasuarina* shrubland and mallee species including *E. burracoppinensis* and *E. salubris*) in December 2012; and a further four along the western margin of the sanctuary in predominantly mallee / shrubland habitat in January 2013. Locations are given in Fig. 2.

Narembeen has an annual average rainfall of 332 mm, with the bulk falling in winter (on average 55% falls in the four months May to September). The year following the translocation (2010) was one of drought, with substantially below-average rainfall in winter, spring, and early summer (Fig. 3).
Surveys prior to reintroduction

An initial baseline survey of 150 trap nights using Elliott traps (90 x 100 x 330 mm) and 49 small cage (200 x 200 x 560 mm) trap nights was conducted in October 2007, prior to the closure of the barrier fence, to ascertain what small native species might be present.

An assessment of the occurrence of visible hollows within woodland habitat was made at 56 randomly located sites within the sanctuary in October 2007. Trees were assessed with respect to species, diameter at breast height (DBH), alive or dead, and whether they had visible hollows. While ground-based assessments of hollows typically overestimate the availability of suitable hollows for a particular species (Whitford 2002), this approach was useful in providing a broad indication of habitat suitability.

Additional surveys to monitor and control exotic predators commenced just prior to the completion of the barrier fence in early 2008. Spotlight surveys were conducted by an observer standing on the back of a 4x4 utility vehicle using a 100W spotlight. Surveys typically took in the entire road network and boundary track of the sanctuary (about 20 km) and were run for several hours from last light.

Sourcing animals for translocation

Phascogales for translocation were derived from sites between Wagin and Narrogin (Fig. 1) where the species had been caught in recent prior surveys (Short and Hide 2012). Five trap lines of 25 traps were set at each location in the late afternoon and checked early the following morning. Traps were baited with peanut butter, rolled oats and sardines. Captured phascogale were weighed, measured and individually marked using ear notches. Animals selected for translocation (some > 26 g were required to fit radio-collars) were held in calico bags and then placed inside Elliott traps. Twenty phascogales were transported in an air-conditioned vehicle to Wadderin in a travel time of c. 3 hours. They were released at dusk on the day of capture into or adjacent to pre-installed nest boxes. The three release sites were in woodland habitat in the centre and north of the sanctuary and were selected based on the perceived quality of foraging habitat and potential nesting hollows. A subset of the phascogales were radio-collared.

Phascogale for a subsequent translocation in 2010 were sourced from a physiological study at Curtin University (Pusey et al. 2013). They had been wild-caught from a private remnant south of Narrogin in April 2010, but held for about six weeks prior to translocation. Their transport to Wadderin and release was similar to that described for the 2009 release. They
were released as three pairs and a single male across four locations spread along a two km north-south axis of the sanctuary.

**Monitoring following release**

Initial monitoring of translocated phascogales was by radio-telemetry and by trapping with Elliott traps. Radio-collars were single-stage transmitters (LTM 379) with mortality sensor fitted to a cable tie (sourced from Titeley Electronics, Ballina, NSW). Each collar weighed 1.3 g and had a nominal battery life of 23 days, although most failed within 6-12 days. Transmitters failed within 6-12 days. All collars were successfully removed at the end of their battery life or shed by the phascogale. Animals were located during the day by tracking them to nest sites using a receiver connected to a three-element yagi antennae. Phascogales were located at night by walking in to a signal until the animal was detected in the beam of a head-torch. All collars were successfully removed at the end of their battery life or were shed by the phascogale.

In addition, lines of 25 Elliott traps (spaced at c. 10 - 15 m intervals within the line and baited with universal bait) were set to cover as much of the area of the sanctuary as possible. The locations of lines were informed by the initial release locations and subsequent radio-telemetry locations. Trapping with Elliott traps continued for two years (nine sessions from April 2009 to March 2011; 5141 trap nights), avoiding the period after the male die-off when females were lactating (August to November). Trapping (c. 200 trap nights) was conducted in apparently suitable habitat beyond the predator-proof fence in January and March 2010, in an effort to detect dispersing animals. Trapping became a far less effective method of monitoring once brush-tailed bettongs (*Bettongia penicillata*) had been released into the sanctuary in June 2010 due to high levels of trap disturbance and hence was largely discontinued.

Home ranges and range length (the longest linear dimension of the range) were calculated for phascogales with ≥ 5 known locations derived from radio-tracking and/or trapping. Home range sizes were calculated using Ranges8 (Anatrack Ltd) software. Minimum convex polygons (MCP) were calculated using 100% and 80% of available locations for each individual.

Nest boxes were checked periodically to determine whether there was any recent use by phascogales. This was determined by the presence of fresh (black) scat, by the presence of a formed nest, and/or by the observation of an animal or animals within the box.
**Results**

*Pre-release surveys for fauna*

The only mammal caught in 199 trap nights prior to translocation of phascogales was a black rat (*Rattus ratus*). Eight spotlighting sessions over a total of c. 145 km prior to April 2009 commonly yielded owls (*Ninox* sp.) and tawny frogmouths (*Podargus strigoides*), potential predators of phascogale. There were no sightings of foxes and only a single sighting of a feral cat. There was no evidence for the presence of pythons, another potential predator. Sand monitors (*Varanus gouldii*) were present in low numbers, but are terrestrial and diurnal, and are unlikely to be a significant predator of phascogales.

*Habitat assessment*

Twenty per cent of 171 trees assessed had visible hollows. The principal hollow-forming eucalypts were York gum and salmon gum. Around 60% of measured York gums and 50% of measured salmon gum had hollows. Incidence of hollows was strongly linked to tree DBH: > 32 cm (n = 13; 46%); > 48 cm (n = 9: 78%); and > 64 cm (n = 3: 100%). Hollows occurred in 8% of rock sheoak (n = 51). No hollows were recorded in other mid-storey species measured (e.g. *Acacia* spp., *Melaleuca* spp., *Leptospermum* spp., *Calothamnus* spp., *Santalum* spp.).

Areas of dense rock sheoak around the margins of granite outcrops were perceived to be important foraging areas for phascogale. Additionally, areas of dense *Melaleuca* spp. / tamma bush *Allocasuarina campestris* associated with mallee/shrubland habitat were considered potential areas for foraging. These were predominantly in the south-west and north-west of the reserve.

*Releases*

Twenty seven phascogale were translocated to Wadderin over 14 months (Table 1). An initial 20 animals transferred in April 2009 were wild caught at three sites north of Wagin (Fig. 1). Males averaged 43.5 ± 1.3 g (mean ± s.e.; n = 8) in body weight and females averaged 31.3 ± 1.1 g (n = 12).

The remainder were transferred from Curtin University in early June 2010, after previously being wild-caught. They had higher average body weights at transfer (males: 53.7 ± 1.5 g (n = 4); females 38.1 ± 2.4 g (n = 3)) than the previous release.

*Movements and home range*

Two of six radio-collared animals dispersed substantial distances on the first night of their release (a female moved 670 m and a male 625 m). The female dispersed a further 540 m on
the following night to the north-east boundary. After these initial movements, both settled down and found what appeared to be high-quality hollows for diurnal shelter. The remaining four collared animals (two males and two females) stayed within 350 m of their release site and established home-ranges and nest hollows. No animals were observed to leave the sanctuary during the two weeks of radio-tracking following release. Radio-collared phascogales mostly utilized hollows in mature York gums for their day-time refuge sites (27 of 31 records: 87%). Other day-time locations were in rock sheoak (2), salmon gum (1), and in a rock crevice in a granite outcrop (1). One female used five separate refuge hollows over seven nights tracked. Others used the same nest location for successive days. A collared male and a collared female appeared to share a hollow on the third day after release, with both continuing to return to the same hollow for the subsequent three days tracked. No phascogales were recorded using nest boxes during the radio-tracking period. All collared animals survived the radio-tracking period.

Trapping of phascogales during the post-release period yielded 86 captures (1.7 per 100 trap nights) and provided data on survival and location of most translocated animals as well as animals born in situ. Animals released after trapping were seen to enter nest boxes on four occasions.

Most locations in 2009 were close to release locations in the centre and north of the sanctuary (Fig. 4). In 2010, trapping indicated there was some movement into the south-east and south-west of the sanctuary. The first records of phascogales outside the sanctuary were in 2011 – to the south-east in a nest box in rock sheoak adjoining the golf course in January; and to the south-west in shrubland contiguous with the sanctuary in September.

Minimum convex polygons for translocated phascogales with more than five locations from either trapping or a combination of trapping and radio-telemetry (11 of the 20) gave a mean home range area of 13.8 ha for males and 6.7 ha for females (100% minimum convex polygon). Range sizes were considerably smaller for 80% minimum convex polygon: 2.6 ha for males and 2.1 ha for females (Table 2). Outlying locations omitted in calculation of 80% minimum convex polygons were recorded in mid-June for three of the four males, suggesting increased movements associated with the mating season. In contrast, release locations were outliers for 4 of the 7 females. Ranges, as assessed by 80% polygons, were variable in both sexes, ranging from less than 1 ha to c. 7 ha.
Survival

Only two of 20 individuals from the 2009 release, both female, were not trapped post-release. Their fates were unknown. Males were more readily trapped than females. All translocated males were captured with average number of captures per individual of 3.9 in the two months between their release and their post-mating die-off in July (range: 3 - 6 captures). In contrast, only seven of 12 females were captured during this period at an average of 1.25 captures per individual (range: 0 – 3). None of the translocated males were detected after trapping in June (seven weeks after release), consistent with the expected male die-off following winter breeding (Fig. 5).

Trapping after the 2009 breeding season (December 2009 and January 2010) revealed that nine of the 12 translocated females were alive 8-9 months post-release - a survival rate of > 75% (Fig. 5). However, known survival declined through autumn and winter 2010. At least a quarter of original translocated females (3 of 12) persisted to the start of the 2010 breeding season. One original translocated female was trapped in March 2011, 23 months after her release. Few data are available on the survival of the 2010 release, due largely to a lack of trapping in the immediate period after their release. A single male was recaptured on June 30, four weeks after release.

Weight

Phascogales typically gained weight following their release into Wadderin and as they increased in age (Fig. 6). Weights of males and females born in situ and measured in March-April 2010 were not significantly different from weights of translocated males and females of April 2009 (males: 45.3 g v. 43.5 g; females: 30.6 g v. 31.3 g; $F_{1, 33} = 0.22; P = 0.64$). Weights of phascogales did not appear unduly affected by the drought of 2010. There was no significant difference in weights of Wadderin phascogales born in situ and measured in May-June 2010 and Curtin phascogales released into Wadderin in June 2010 (males: 58.1 g v. 53.7 g; females: 35.7 g v. 38.1 g; $F_{1, 9} = 0.15; P = 0.71$). Similarly, two females measured in November 2010, near the end of lactation, did not differ significantly in weight to similar females measured in December the previous year (females in 2010: 38.37 g v. females in 2009: 35.92 g; $F_{1, 10} = 0.84; P = 0.38$).

Reproduction and recruitment

Seven of nine females known to have survived the 2009 breeding season appeared to have each raised eight young. Four were caught in early December and had eight nipples expressing milk; a further three were caught in January and had eight even-sized regressing
Of the remaining two, one had six nipples expressing milk and one had a single nipple expressing milk. Hence the mean (± SE) number of young likely to have been weaned per female was 7.0 ± 0.89 (n = 9).

Fifteen new females and four new males were caught immediately following the 2009 breeding season (females from December 2009; males from March 2010). The female young of the year, when first caught in December and January, were significantly smaller than their mothers – mean 26.5 g; (n = 8) cf. 36.7 g (n = 9) F₁,₁₅ = 42.8; P < 0.001 (Fig. 6), but also differed in intensity of colouration. This was particularly evident in the colour of the base of the tail, with older females having a redder colouration.

No specific trapping was undertaken for phascogales in the 2010 or 2011 breeding seasons, but two females were caught in each as by-catch while trapping for bettongs. Two females caught in late November 2010 had eight and five lactating nipples (mean of 6.5 per female). Of two caught in mid-September 2011, one had eight young in the pouch and the other eight lactating nipples (mean of 8.0 per female).

Longer term persistence

Longer term persistence through to January 2015 was assessed from nest boxes. Phascogales made almost immediate use of nest boxes within the sanctuary, with earliest use detected within three months of translocation (Table 3). The percentage of boxes in active use increased to >60% within the sanctuary from mid-2010 and continued at this level through to early 2015. Boxes placed outside the predator-proof fence beginning in late 2010 were quickly utilized – with some taken up within two months of erection.

Discussion

Reintroduction to Wadderin Sanctuary

The translocation of red-tailed phascogale to Wadderin Sanctuary has been successful in that animals have survived and bred over a >5 year period, expanding into all available habitat and to adjoining bushland and a nearby remnant. Measured attributes of the released phascogales were similar to that of populations assessed elsewhere in the Western Australian wheatbelt and there were none of the problems of dispersal reported for releases of phascogales elsewhere.

Males released at Wadderin in April 2009 persisted no longer than three months post–release. This is consistent with what is known of the biology of the species, with males exhibiting post-mating mortality and only living for 11.5 months (Bradley 1997). In contrast, five of the
12 females released into the sanctuary were detected in late autumn and winter 2010 and another at the end of the breeding season in December 2010. Hence it appears that as many as 50% of females may have survived to breed in their second season. An original translocated female was detected as late as March 2011, nearly two years after translocation. This result is similar to the observations of Bradley (1997) who observed female phascogales at Yornaning Nature Reserve to survive for up to three years, with approximately 35% surviving and breeding into their second year and 10% surviving to a third year.

Radio-tracking during the early weeks of the translocation revealed that phascogales mostly used York gum for shelter and foraged in dense areas of rock sheoak bordering granite outcrops. Phascogale have a preference for vegetation with denser canopies (Kitchener 1981; Short et al. 2011) such as those of rock sheoak. Kitchener (1981) reported also that phascogale used areas of *Acacia lasiocalyx* with mid-dense understorey of *Allocasuarina campestris*. He considered *Allocasuarina* most important (with ranking from *A. huegeliana*, to *A. campestris* to *A. acutivalvis*), whether in upper or lower stratum in contrast to mixed shrub assemblages dominated by *Melaleuca* that were not favoured. Such habitats occur at Wadderin also, but we found little evidence for their use in the period immediately following translocation. The first record of a phascogale caught in tamma (*A. campestris*) shrubland was in November 2010, 18 months after translocation. Nest boxes placed in these habitats in later years were quickly occupied and probably facilitated greater use of these habitats where natural shelter sites appear scarce.

Past attempts to reintroduce phascogales (both *P. tapoatafa* and *P. calura*) have reported problems with large-scale movements of males following translocation (Soderquist 1994, Young 2007). For example, in trial releases of *P. calura* in Alice Springs (see below), radio-collared males from two releases rapidly left the release site. One male moved > 500 m in the first night before moving out of range. In another release, males moved > 2.5 km in the first night and were not subsequently located. These large movements were attributed to intrasexual aggression (Young 2007). Soderquist (1994) reported similar problems with release of *P. tapoatafa* in Gippsland, particularly when males were released in the absence of females. This was not a problem encountered at Wadderin, where all males remained close to their release site and reintroduced females. Males moved over a mean range of 13.8 hectares (100% MCP) with mean range length of 669 m. There was no overlap between the four males for which home ranges were calculated for the period from release to mid-June.
Similarly, females at Wadderin remained close to their release locations. Their mean range size was 6.7 ha (100% MCP) and mean range length was 604 m. This is similar to home ranges estimated by Young (2007). In that study, four female phascogales were radio-tracked for 5-13 nights in autumn 2007. Mean home range size was 6.0 ha based on 100% MCP. Average range length was 417 m. As at Wadderin, there was substantial overlap in the ranges of females. This contrasts with the largely exclusive home ranges for females reported for *P. tapoatafa* (Traill and Coates 1993, Soderquist 1995) and presumably allows *P. calura* to exist at higher densities: an advantage in remaining small and isolated remnants in the Western Australian wheatbelt.

Phascogales at Wadderin bred within months of translocation with females producing a mean of 7.0 young. This is similar to the value of 7.5 young reported by Bradley (1997) for the population at Yornaning. Evidence from checks of nest boxes at Wadderin (and captures of lactating females in 2010 and 2011) indicated breeding in all subsequent years.

Spotlighting at Wadderin revealed the regular presence of owls *Ninox* sp. and tawny frogmouths (with barn owls (*Tyto alba*) seen on occasion). These are all possible predators of phascogales. Owls are known to prey on brush-tailed phascogales (Van Dyck and Gibbons 1980; Soderquist and Serena 1994). Despite this, their presence at Wadderin did not appear to influence the outcome of the reintroduction.

Phascogales at Wadderin persisted despite a severe drought in 2010 (180 mm rain fell, just 54% of long-term average of 332 mm and the second lowest year of rainfall at Narembeen since records began in 1927). Rhind and Bradley (2002) reported a significant decrease in growth and size of brush-tailed phascogales during a drought year in south-west Western Australia, and this was accompanied by a population decline in the following year. At Wadderin, there was no apparent decline in body weight of phascogales, but there was an indication of a slight decline in number of young per female (to 6.5 per female).

Individual *P. tapoatafa* are known to use as many as 19 nest trees (mean 11.4) within their home range (van der Ree *et al.* 2006), so the addition of nest boxes to supplement existing tree hollows at Wadderin is likely to have contributed to the successful establishment of phascogales. Overall, the high level of usage of nest boxes both within and outside the sanctuary (including regular sightings of animals within the boxes) suggest a healthy population persisting through to 2015. The ongoing maintenance and monitoring of nest boxes
at Wadderin and nearby bushland will be important both to the long-term persistence of the population and to our knowledge of the long-term fate of this population.

**Translocations compared**

There have been two other attempts to translocate *Phascogale calura*: one to a reserve on the southern margin of its current range near Kojonup in Western Australia and the other to central Australia within the species known historical range but 2,000 km to the north-east of its current range (Fig. 1). Table 4 summarises attributes of release technique and release sites for the three translocations.

In May 2010, 20 red-tailed phascogales (eight male, twelve female) were reintroduced to an unfenced reserve of 389 ha, 18 km north-east of Kojonup (A. Sanders, pers. com.). This site is on the south-western margin of the concentration of recent positive records in the western wheatbelt of Western Australia (see Fig. 1 in Short et al. 2011; Short and Hide 2012) and is in the typical wandoo – rock sheoak habitat favoured by the species. Thirty nest boxes were added to the reserve to aid the establishment of phascogales. Animals were sourced from Boyagin, East Yornaning, Pingeculling and Tutaning Nature Reserves (Fig. 1). A further 10 phascogales (six male, four female) from Boyagin, East Yornaning and Pingeculling were added in May 2011. Phascogales were still present in May 2014 - six individuals were caught in 400 trap nights with Elliott traps, at least ten individuals were observed in nest boxes, and 90% of nest boxes showed some use (A. Sanders, pers. com.). Hence, the reintroduced population has been extant for 4 years.

There were three releases of phascogales into Alice Springs Desert Park (ASDP) in 2006 - 2007 (W. Caton, pers. com.). The park has a core area of 26 ha enclosed by a predator-proof fence, and is 10 km from the centre of Alice Springs and at the base of the West McDonnell Ranges. Thirty two red-tailed phascogales (11 male, 21 female) were released in 2006 and 2007 (Foster and Andrews 2007; Young 2007). These animals were captive-bred, derived from a colony established in 2001 from wild-caught animals from the south-west of Western Australia (East Yornaning, Yackrikine, North Boundain and West Ashby (see Fig. 1 for locations)). The captive colony was managed to minimise inbreeding and had passed through seven generations in captivity (Foster and Andrews 2007)). Animals were released into a habitat of mulga *Acacia aneura*, witchetty bush *A. kempeana* and bloodwoods *Corymbia opaca* using a soft-release technique (held variously for 10 days to 4 months in a pen prior to release). While the fate of this trial is poorly documented, it is known that 6 of 10 females
from the July 2006 release survived for at least three months with 2 of the 6 carrying young (Foster and Andrews 2007). Four radio-collared females from the February 2007 release were known to have persisted for 4-5 weeks post-release (Young 2007). There were occasional sightings in nest boxes and in ground-level “irrigation boxes” in the first year after release, but there have been none since and the reintroduction is believed to have failed (Bruce Pascoe, ASDP, pers. com. 2015).

Phascogales released at Alice Springs fed on a diet predominantly of arthropods (mainly Araneae, Coleoptera, Blattodea, Diptera and Hymenoptera) (Stannard et al. 2010). Mammalian hairs from domestic house mice (Mus musculus), from small native mammals (Pseudomys desertor and Sminthopsis macroura), and from a small insectivorous bat (Nyctophilus geoffroyi) were present also in faecal samples. There was also some evidence of predation on small birds and reptiles (Stimson’s python Antaresia stimsoni). This diet, primarily insectivorous but with opportunistic predation on small mammalian, avian and reptilian species, closely mirrors that found for wild phascogales in southern Western Australia (Kitchener 1981) and suggests that food availability was not a limiting factor in the outcome of the reintroduction.

Phascogales at Alice Springs were reported to nest in vacant bird’s nests (large domed nests of sticks) constructed by grey-crowned babblers Pomatostomus temporalis in whitewood Atalaya hemiglauca (21 records) and mulga trees Acacia aneura (6). They nested also in hollows in bloodwood Corymbia opaca (19 records) and ironwood Acacia estrophiolutata (1) (Young 2007). The high use of bird’s nests and the description of habitat as having “a relatively young vegetation structure” (Young 2007) suggests a shortage of suitable tree hollows for nesting and shelter. Trail and Coates (1993) reported P. tapoatafa using the nests of white-browed babbler (P. superciliosus) in areas where the abundance of hollows was low, and considered such nests to confer less thermoregulatory advantage and predator protection than tree hollows.

Factors common to the reintroductions to Wadderin and Kojonup included: 1). The presence of high quality habitat of old-growth eucalypts in close juxtaposition with rock sheoak or other dense mid-storey species, providing both adequate shelter and breeding sites as well as areas of dense canopy suitable for foraging; 2). The presence of nest boxes throughout the available habitat to supplement existing hollows, particularly in extensive areas of rock sheoak without embedded eucalypts as well as more marginal shrubland habitats; 3). The
absence or reduced predation from foxes at both sites (and cats at Wadderin); and 4). The use of wild-caught stock.

The isolation of habitat at Wadderin and Kojonup by surrounding farmland has not influenced the outcome of these translocations to date, but may influence longer-term survival of populations by limiting the ability of phascogale to recolonise after a catastrophic event. The higher densities likely to be maintained at Wadderin in the absence of cat and fox predation may act to ameliorate this potential threat.

The reintroduction to Alice Springs differed in a number of ways from that to Wadderin and Kojonup: 1). This reintroduction was the only one of the three to utilise captive-bred stock for release; 2). Males were reported to rapidly disperse away from the reintroduction site; 3). Exotic predator control may not have been at a sufficient scale given the small size of the fenced area, the likely dispersal of phascogale beyond this area, and the abundance of feral cats beyond the fence (Bruce Pascoe, pers. com. 2015); 4). There may have been a shortage of suitable natural hollows; and 5). The site is likely to have a broader suite of arboreal predatory reptiles than at the other two sites, including an arboreal monitor.

It is unclear to what extent, if any, these factors contributed to the outcome of this reintroduction. Soderquist (1994) reported the outcome of trial releases of captive-raised brush-tailed phascogales to Gippsland in Victoria in the early 1990s. In one trial, 50% of females were killed in the first week following release, attributed to predation from foxes, feral cats and goannas (presumably, the partly arboreal lace monitor *Varanus varius*). The apparent naivety of captive raised animals was considered a factor. Fox control provided only a marginal improvement in survival. The naivety induced by captive rearing proved a major factor in reduced survival and was overcome by penning females weaning young in “nursery cages” in the bush. These contained the mothers, but allowed their young to disperse at the end of the period of weaning. However, this was not considered a practical option for red-tailed phascogale because of their smaller size (Foster and Andrews 2007). In a study evaluating the effects of captive experience of reintroduction survival in carnivores, Jule et al. (2008) found that captive-born individuals were far less likely to survive, being susceptible to starvation and unsuccessful predator/competitor avoidance. These findings are consistent with those of Soderquist (1994) for phascogales.

Soderquist and Lill (1995) established that in natural populations of *P. tapoatafa* males dispersed at least 3 km from their natal nest at about 3 weeks after weaning, but if they
dispersed into unoccupied habitat would often return to the natal site. At Wadderin, the young
male recruits from the first breeding season after reintroduction appeared in the trappable
population 3 months after the females indicating they may have dispersed and then returned.
This suggests the possibility that the rapid dispersal of reintroduced males away from the
release site at Alice Springs may have been related in part to the timing of the releases
(January and February), coinciding with the time of natural dispersal of males. In contrast,
reintroductions of males to Wadderin and Kojonup (Table 4) were in April to June, 4-6
months post-weaning.

The small area protected from cat and fox predation at Alice Springs and the proximity to a
large town with a reported abundant feral cat population may have been a contributing factor
in the failure of this reintroduction. *P. calura* are regularly brought in by domestic cats (Short
and Hide 2012), suggesting that feral cats may have a substantial impact where they co-occur.
Similarly, *P. tapoatafa* are known to be predated by both cats and foxes (Soderquist 1994).
The vulnerability of released phascogales may have been exacerbated by their captive origin.
The high reproductive output and semi-arboreality of phascogales provide some protection
from predation by cats and foxes, but the species may still be vulnerable in the early stages of
a reintroduction, particularly in more arid habitats lacking a dense mid-storey canopy in close
juxtaposition to abundant secure hollows.
The presence of arboreal monitors such as *Varanus tristis* and pythons such as *Morelia bredli*
not present at the other sites may also have been a contributing factor in the failure of
phascogales to establish at Alice Springs. For example, *V. tristis* is described as “foraging
widely (up to 2 km per day) in search of food, ascending trees to investigate all likely
hollows” (Wilson and Knowles 1988).
Future reintroductions of *P. calura* are planned at increasing distances from the remaining
range of the species (for example, captive stock to the 7,800 ha predator-proof enclosure at
Mount Gibson in the northern wheatbelt of Western Australia: Groom *et al.* 2015). These
may provide the opportunity to further examine factors possibly impacting on translocation
success in this species. This would benefit from hypothesis testing (Soderquist 1994), but at
minimum will require a robust system to monitor survival of reintroduced animals and likely
threatening processes over several years following reintroductions.
Conclusion

Red-tailed phascogales have successfully established in woodland habitat at Wadderin Sanctuary in the eastern wheatbelt beyond the margin of their current range and have been extant for > 5 years. Comparing and contrasting management and habitat elements with other reintroductions of this species suggest abundant quality nesting sites in old-growth eucalypts and nest boxes, a dense mid-story canopy for foraging in close juxtaposition to shelter, and a degree of effective predator control were common to the successful reintroductions. Both reintroductions used wild-caught stock and neither sites had arboreal monitors such as *Varanus tristis*. Regular ongoing monitoring was essential to the interpretation of outcome and was relatively easily achieved by use of nest boxes. The success of reintroductions at Wadderin and Kojonup, where, presumably, the species has become locally extinct in the recent past, suggests that other factors may come into play over time. Elevated levels of predation from foxes and feral cats, the ongoing effects of small population size and isolation resulting from fragmentation of habitat by past agricultural clearing, reproductive failure in years of extreme drought, and their combination are the most likely factors to threaten long-term survival.

Acknowledgements

The work reported in this paper was carried out with an approved translocation proposal and licence issued by the Department of Environment and Conservation, Western Australia. The Department facilitated the sourcing of animals from Curtin University for transfer to Wadderin. We thank Exetel (Steve Waddington) and FAME (Cheryl Hill) for their funding support and Narembeen community members Mel Bristow, Brian Cusack, Brendan Johns, the late Brian Price, and other community members for their ongoing assistance. We thank the farmers at Wagin who freely gave us access to their land to trap phascogales for transfer to Wadderin and Angela Sanders and Wendy Foster who provided unpublished reports. We also thank Arthur Kershaw and Tim Coveley for constructing nest boxes for the project. For field assistance we thank Chris Hannan, Bec McCracken and Megan Stone. Drs Mike Calver and Blair Parsons provided valuable comments on an earlier draft of this manuscript.

References


Foster, W. K., Bradley, A. J., Caton, W., and Taggart, D. A. (2006). Comparison of growth and development of...
Reintroduction of red-tailed phascogale to wheatbelt Western Australia


Fig. 1. Location of Wadderin Sanctuary in south-western Australia and sites mentioned in text. 1. Wadderin Sanctuary; 2. Kojonup; 3. Alice Springs Desert Park; 4-7. source locations for Wadderin reintroduction; 8-11. source locations for Alice Springs reintroduction; 8, 12-14. source locations for Kojonup reintroduction. Grey shading gives the area of the wheatbelt in southern Western Australia.
Fig. 2. Wadderin Sanctuary and nearby bushland including the Wadderin railway reserve (to east). The area shown white is farmland. Nest boxes for red-tailed phascogales were distributed widely throughout the sanctuary and nearby bushland.
Fig. 3. Annual rainfalls at Narembeen for years of translocation of red-tailed phascogale. The horizontal dashed line shows the long-term annual average rainfall (332 mm).
Fig. 4. Locations of phascogales at Wadderin Sanctuary in 2009 and 2010.
**Fig. 5.** Survival of red-tailed phascogale reintroduced to Wadderin in April 2009.

**Fig. 6.** Weight changes of phascogale (± SE) at Wadderin – translocated animals and those born *in situ*. 
Table 1. Source of red-tailed phascogale translocated to Wadderin Sanctuary. Locations are given in Fig. 1(# 4 - 7 respectively).

<table>
<thead>
<tr>
<th>Date</th>
<th>Source location</th>
<th>Latitude</th>
<th>Longitude</th>
<th># of animals transferred (m:f ratio)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr 21, 2009</td>
<td>Private remnants (Ballagin and Tarwonga Roads, north of Wagin)</td>
<td>-33.1807</td>
<td>117.0528</td>
<td>5 (1:4)</td>
</tr>
<tr>
<td>Apr 27, 2009</td>
<td>Private remnant (Great Southern Highway abutting the Arthur River near Piesseville)</td>
<td>-33.1688</td>
<td>117.2553</td>
<td>8 (4:4)</td>
</tr>
<tr>
<td>Apr 29, 2009</td>
<td>Private remnant along the Arthur River on Ballagin Road, north of Wagin</td>
<td>-33.2109</td>
<td>117.1760</td>
<td>7 (3:4)</td>
</tr>
<tr>
<td>Jun 2, 2010</td>
<td>Private remnant south of Narrogin (via Curtin University)</td>
<td>-33.0332</td>
<td>117.2327</td>
<td>7 (4:3)</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>27 (12:15)</td>
</tr>
</tbody>
</table>
Table 2. Home range sizes of translocated phascogales at Wadderin Sanctuary calculated using a minimum convex polygon and utilizing either 100% of 80% of available location points for each individual. Only individuals with > 5 locations are given.

<table>
<thead>
<tr>
<th>Individual</th>
<th>Gender</th>
<th>n</th>
<th>Period of records (weeks)</th>
<th>Home range area (ha)</th>
<th>Range length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100%</td>
<td>80%</td>
</tr>
<tr>
<td>#3</td>
<td>F</td>
<td>6</td>
<td>14.1</td>
<td>0.5</td>
<td>0.04</td>
</tr>
<tr>
<td>#5</td>
<td>F</td>
<td>6</td>
<td>14.1</td>
<td>3.0</td>
<td>1.5</td>
</tr>
<tr>
<td>#6</td>
<td>F</td>
<td>8</td>
<td>1.7</td>
<td>15.8</td>
<td>1.3</td>
</tr>
<tr>
<td>#15</td>
<td>F</td>
<td>8</td>
<td>98.6</td>
<td>2.2</td>
<td>0.4</td>
</tr>
<tr>
<td>#16</td>
<td>F</td>
<td>10</td>
<td>38.4</td>
<td>5.4</td>
<td>1.7</td>
</tr>
<tr>
<td>#18</td>
<td>F</td>
<td>7</td>
<td>57.1</td>
<td>13.6</td>
<td>6.7</td>
</tr>
<tr>
<td>#19</td>
<td>F</td>
<td>6</td>
<td>56.1</td>
<td>5.1</td>
<td>2.1</td>
</tr>
<tr>
<td>mean</td>
<td></td>
<td></td>
<td></td>
<td>6.7</td>
<td>2.1</td>
</tr>
<tr>
<td>#2</td>
<td>M</td>
<td>10</td>
<td>5.3</td>
<td>9.0</td>
<td>1.2</td>
</tr>
<tr>
<td>#7</td>
<td>M</td>
<td>6</td>
<td>7.6</td>
<td>7.5</td>
<td>2.3</td>
</tr>
<tr>
<td>#14</td>
<td>M</td>
<td>11</td>
<td>6.6</td>
<td>37.7</td>
<td>6.2</td>
</tr>
<tr>
<td>#24</td>
<td>M</td>
<td>9</td>
<td>6.9</td>
<td>0.9</td>
<td>0.7</td>
</tr>
<tr>
<td>mean</td>
<td></td>
<td></td>
<td></td>
<td>13.8</td>
<td>2.6</td>
</tr>
</tbody>
</table>
**Table 3.** Results of checks of nest boxes for phascogale activity. Some boxes were unavailable at times due to occupation by bees (3 of 35 in September 2014 and January 2015) or from damage to the box.

<table>
<thead>
<tr>
<th>Date</th>
<th># boxes checked/available</th>
<th>No recent activity (%)</th>
<th>Total active (%)</th>
<th>Fresh dung only</th>
<th>Active nest + fresh dung</th>
<th>Animal + nest + dung</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inside Sanctuary</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jul-09</td>
<td>17</td>
<td>8</td>
<td>9 (53%)</td>
<td>6</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Sep-09</td>
<td>20</td>
<td>12</td>
<td>8 (40%)</td>
<td>5</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Oct-09</td>
<td>22</td>
<td>17</td>
<td>5 (23%)</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Jan-10</td>
<td>22</td>
<td>20</td>
<td>2 (9%)</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>May-10</td>
<td>19</td>
<td>?</td>
<td>? (&gt;32%)</td>
<td>?</td>
<td>?</td>
<td>6</td>
</tr>
<tr>
<td>Jul-10</td>
<td>18</td>
<td>5</td>
<td>13 (72%)</td>
<td>9</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Oct-10</td>
<td>21</td>
<td>8</td>
<td>13 (62%)</td>
<td>1</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>Jan-11</td>
<td>22</td>
<td>9</td>
<td>13 (59%)</td>
<td>4</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>May-11</td>
<td>21</td>
<td>5</td>
<td>16 (76%)</td>
<td>3</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Sep-11</td>
<td>22</td>
<td>5</td>
<td>17 (77%)</td>
<td>2</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>Jul-13</td>
<td>25</td>
<td>4</td>
<td>21 (84%)</td>
<td>0</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>Sep-14</td>
<td>20</td>
<td>3</td>
<td>17 (85%)</td>
<td>0</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>Jan-15</td>
<td>21</td>
<td>6</td>
<td>15 (71%)</td>
<td>1</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td><strong>Outside Sanctuary</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan-11</td>
<td>5</td>
<td>3</td>
<td>2 (40%)</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>May-11</td>
<td>5</td>
<td>0</td>
<td>5 (100%)</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Sep-11</td>
<td>6</td>
<td>0</td>
<td>6 (100%)</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Jul-13</td>
<td>9</td>
<td>0</td>
<td>9 (100%)</td>
<td>0</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Sep-14</td>
<td>8</td>
<td>3</td>
<td>5 (63%)</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Jan-15</td>
<td>9</td>
<td>2</td>
<td>7 (78%)</td>
<td>0</td>
<td>6</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 4. Three reintroductions of red-tailed phascogales compared.

<table>
<thead>
<tr>
<th>Release techniques</th>
<th>Wadderin Sanctuary</th>
<th>Kojonup Bush Heritage Reserve</th>
<th>Alice Springs Desert Park</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin of stock</td>
<td>Wild-caught</td>
<td>Wild-caught</td>
<td>Captive-bred</td>
</tr>
<tr>
<td>Type of release</td>
<td>Hard</td>
<td>Hard</td>
<td>Soft, 3 x 6 x 2 m enclosure for &gt; 4 months; 4.5 x 3 x 2.2 m for 10 days</td>
</tr>
<tr>
<td>Composition of release</td>
<td>8 males plus 12 females; 4 males and 3 females</td>
<td>8 males plus 12 females; 6 males plus 4 females</td>
<td>10 females; 6 males; 11 females plus 5 males</td>
</tr>
<tr>
<td>Habitat</td>
<td>Eucalypt and rock sheoak Allocasuarina huegeliana woodland, mallee, shrubland</td>
<td>Eucalypt and rock she-oak woodland</td>
<td>Mulga (Acacia aneura) and witchety scrub (A. kempeana) shrubland</td>
</tr>
<tr>
<td>Old-growth eucalypts</td>
<td>Yes, York gum Eucalyptus loxophleba, salmon gum E. salmophloia, plus various mallees</td>
<td>Yes, E. wandoo</td>
<td>Bloodwood Corymbia opaca, but habitat described as having “relatively young vegetation structure”</td>
</tr>
<tr>
<td>Annual rainfall</td>
<td>332 mm</td>
<td>526 mm</td>
<td>279 mm</td>
</tr>
<tr>
<td>Nest boxes provided</td>
<td>Yes, 22 increased to 35</td>
<td>Yes, 30</td>
<td>Yes, 11 within 150 m of release pen</td>
</tr>
<tr>
<td>Supplementary food provided</td>
<td>No</td>
<td>No</td>
<td>Yes, for 1 week after release</td>
</tr>
<tr>
<td>Arboreal reptilian predators</td>
<td>No</td>
<td>Carpet python Morelia spilota</td>
<td>Yes, e.g. Varanus tristis, Morelia bredli, Antaresia stimsoni</td>
</tr>
<tr>
<td>Fox and cat control</td>
<td>Yes, exclusion fence (430 ha)</td>
<td>Yes, baiting for foxes to 2012, then suspended due to possible positive impact on feral cats</td>
<td>Yes, exclusion fence (26 ha). Feral cats abundant outside due to proximity to town</td>
</tr>
<tr>
<td>Outcome</td>
<td>Extant, &gt; 5 years</td>
<td>Extant, &gt; 4 years</td>
<td>Unsuccessful, extant &lt; 1 year</td>
</tr>
</tbody>
</table>