Biological Conservation 144 (2011) 2863–2872

Contents lists available at SciVerse ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

# Predation determines the outcome of 10 reintroduction attempts in arid South Australia

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ARTICLE INFO

*Article history:*
Received 5 April 2011
Received in revised form 4 August 2011
Accepted 5 August 2011
Available online 3 September 2011

*Keywords:*
Reintroduction
Translocation
Threatened species
Success criteria
Arid zone

ABSTRACT

Ten reintroduction attempts were conducted in and around the Arid Recovery Reserve in northern South Australia between 1998 and 2008. Five locally-extinct mammal species and one reptile species were reintroduced into a fenced Reserve where cats, foxes and rabbits were excluded. Reintroductions of the nationally threatened greater stick-nest rat, burrowing bettong, greater bilby and western barred bandicoot were all considered successful based on short and medium-term success criteria. These criteria included continued survival after 8 years, increased distribution across the large Reserve and, most importantly, recovery after a drought event. The trial reintroductions of the numbat and woma python into the Reserve were unsuccessful due to predation by native avian and reptilian predators respectively. Outside the Reserve, where cats and foxes were present but controlled through poison baiting, reintroduction attempts of the greater bilby and burrowing bettong were unsuccessful. High mortality was attributed to cat and fox predation with dingoes also contributing to post-release mortality in bettongs. However, a reintroduction of burrowing bettongs into a fenced area with low rabbit and cat abundance has, to-date, met short-term and medium-term success criteria. Results suggest that the absence or severe restriction of exotic mammalian predators was the critical factor responsible for the success of the mammal reintroductions. Determining thresholds of predator activity below which successful reintroduction of threatened species can occur, are needed to improve the science of reintroduction biology in Australia.



## 1. Introduction

Reintroduction programs are a tool often used in species recovery programs, both in Australia (Short et al., 1992; Christensen and Burrows, 1994; Gibson et al., 1994; Southgate and Possingham, 1995; Priddel and Wheeler, 1997, 2002) and overseas (Wolf et al., 1998; Seddon et al., 2007). However, most reintroductions of rare or threatened species fail to establish viable populations (Griffith et al., 1989; Dodd and Seigel, 1991; Beck et al., 1994) and the majority of mammal reintroductions onto mainland Australia have also failed (Short et al., 1992; Gibson et al., 1994; Fischer and Lindenmayer, 2000; Short, 2009). Australian practitioners typically attribute failures to predation by exotic predators such as cats (*Felis catus*) and foxes (*Vulpes vulpes*) (Short, 2009), with successful reintroductions occurring on islands or into exclosures where introduced predators are absent (e.g. Richards and Short, 2003). However, studies comparing reintroduction success in adjacent areas with and without exotic predators are necessary to determine the role of predation relative to death from disease, starvation, hyperdispersal and stress, particularly when scavenging by predators could mask the cause of death.

The Australian arid zone mammal fauna (Finlayson, 1941, 1961) and their habitats have been severely altered since European settlement through overgrazing by rabbits (*Oryctolagus cunniculus*) and domestic stock, increased predation from cats and foxes, an increase in artificial watering points and changes to vegetation composition (Friedel, 1985; Morton, 1990; Wilson, 1990). Translocations typically have a poor chance of success unless habitat quality is high (Griffith et al., 1989) but contemporary vegetation condition may not be adequate to support reintroduced herbivorous animals. The few Australian mainland arid zone reintroductions that have occurred have focused on insectivorous species such as bandicoots and bilbies (Christensen and Burrows, 1994; Southgate, 1994; Moseby and O'Donnell, 2003), revealing little about the ability of herbivorous species to re-establish in diminished quality habitat.

Another factor that may thwart reintroduction attempts in the arid zone is the lack of arid-adapted source populations. Droughts and temperature extremes are a feature of arid environments and

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doi:10.1016/j.biocon.2011.08.003

may have exerted considerable selective pressure on mammal populations. Many former arid zone mammal subspecies such as the western barred bandicoot, (*Peremeles bougainville notina*) are now extinct leaving only the more mesic island-dwelling subspecies such as *Peremeles bougainville bougainville* available for reintroduction.

Although the primary aim of any reintroduction is to establish a self-sustaining (Griffith et al., 1989), free-ranging viable population (IUCN, 1998; Fischer and Lindenmayer, 2000), Bajomi (2010) sourced 12 definitions of reintroduction success from the global literature. The four common definitions were: using Population Viability Analysis to predict whether the population will be self-sustaining (Beck et al., 1994); population persistence (Wolf et al., 1998); breeding of the first wild-born generation (Sarrazin and Barbault, 1996; Seddon, 1999); and a positive population growth rate over three generations, or 10 years (IUCN, 1998). Many Australian practitioners also set *a priori* criteria for re-introduction success (Backhouse et al., 1994; Short and Turner, 2000; Richards and Short, 2003; Vale et al., 2004) such as a percentage survival after 12 months, reproduction within 6 months and population

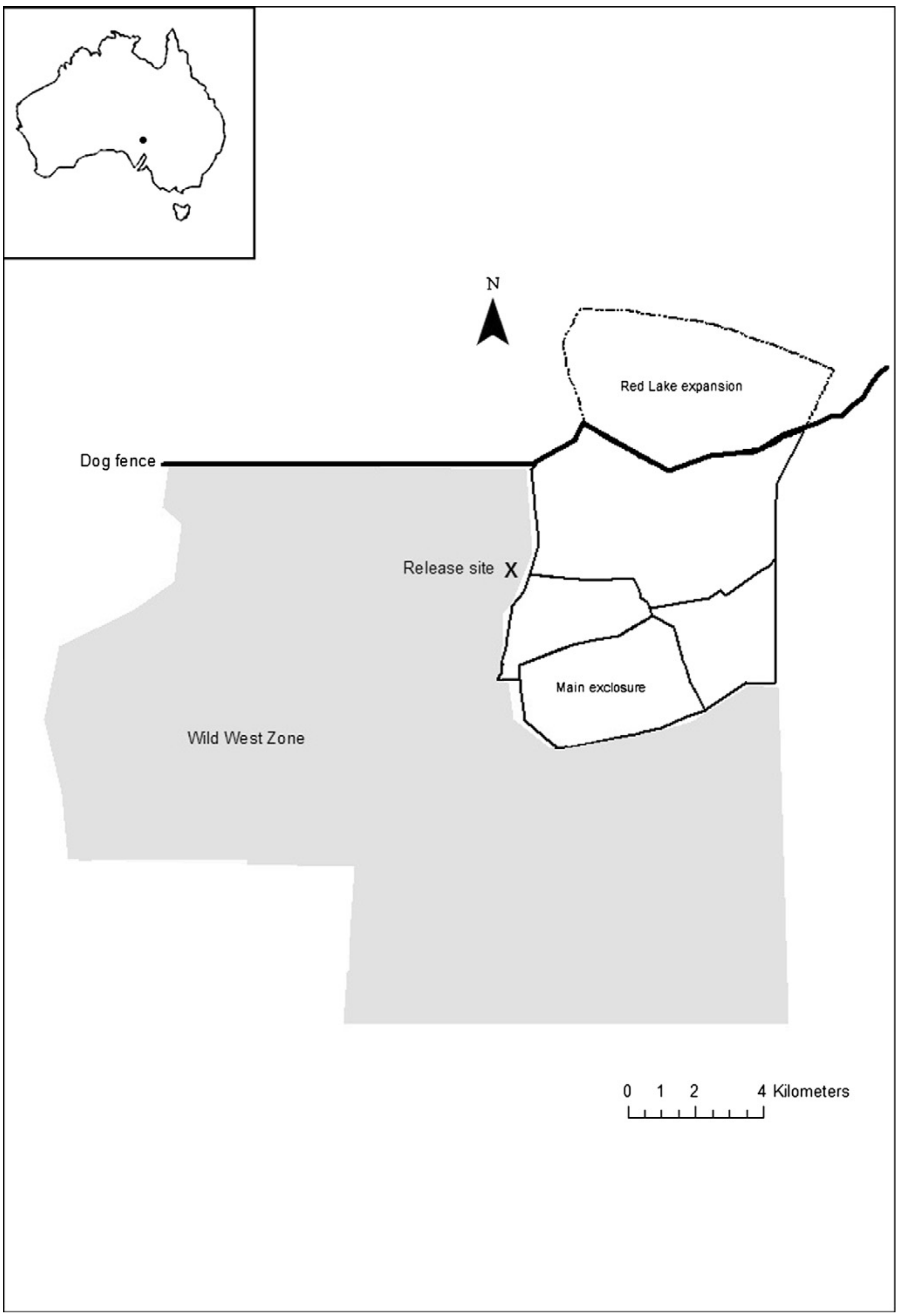


**Fig. 1.** Map of Reserve showing areas of reintroductions (Main Exclosure, Red Lake and Wild West Zone), the dog fence and the release site within the Wild West Zone.

persistence after 5 years. These criteria allow short-term success to be measured through targeted monitoring but may have little bearing on long-term success (see Soorae, 2010).

Ten reintroductions of locally-extinct species were attempted in and around the fenced Arid Recovery Reserve in northern South Australia between 1998 and 2008. Various source populations and release sizes were used at three release locations with no, low or moderate levels of introduced rabbits, cats and foxes. This study outlines the success or failure of each reintroduction and investigates factors affecting reintroduction outcomes. We identified short, medium and long-term success criteria with only the first two stages considered here.

## 2. Methods

### 2.1. Study sites

Established in 1997, the Arid Recovery Reserve (30°29′S, 136°53′E) is a privately owned 123 km$^2$ fenced exclosure situated 20 km north of Roxby Downs in arid South Australia (Fig. 1). Reintroductions were attempted into two paddocks of the Reserve (Fig. 1); the Main Exclosure where cats, rabbits and foxes were eradicated, and the Red Lake Paddock where low levels of rabbits and cats were present and contained. Additional reintroductions were attempted into the adjacent unfenced Wild West Zone where cats and foxes were free-ranging but subjected to ongoing control measures.

The Main Exclosure is a 14 km$^2$ paddock where rabbits, cats and foxes were eradicated in 1999 (Read et al., 2011). An estimated 1000 rabbits (Moseby and Read, 2006) and 6 cats and foxes were removed during eradication. A 1.8 m high wire netting fence with a curved overhang and two electric wires was used to exclude rabbits, cats and foxes (Moseby and Read, 2006). Reintroductions of native fauna occurred either into a small 10 ha release pen within the Main Exclosure or directly into the Main Exclosure itself.

The 26 km$^2$ Red Lake Paddock supports low levels of rabbits and cats. It is surrounded by a 1.15 m high fence with a curved overhang that excludes rabbits, foxes and most cats (Moseby and Read, 2006; K. Moseby pers. obs.). More than 4000 rabbits and three cats were removed over a 5 year period through trapping and poisoning (Read et al., 2011), although both species are yet to be eliminated. No foxes were present in the pen during the study.

The 200 km$^2$ unfenced Wild West Zone is bordered by the Arid Recovery Reserve to the east and the dog fence to the north (Fig. 1). The dog fence is a man-made wire netting fence designed to exclude dingoes (*Canis lupus dingo*) from southern sheep grazing areas. Only the Arid Recovery fence-line formed a significant barrier to rabbits, cats and foxes. Rabbit, cat and fox abundance was higher than that recorded in the Red Lake Paddock but was limited by ongoing control. Cats and foxes were controlled in the Wild West Zone through annual (2002–2004) then quarterly (2005–2006) aerial baiting using Eradicat™ sausage baits (Western Australian Department for Environment and Conservation) or dried meat baits both containing 1080 (monofluroacetate) poison. From 2007, control took the form of bimonthly Eradicat™ ground baiting at a density of 10–25 per km$^2$, opportunistic poison baiting in areas where feral cat tracks were observed, weekly shooting and permanent trapping at up to 10 sites using soft-catch foothold traps. Rabbit control was not attempted.

The Roxby Downs climate is arid, failing to reach its long term average rainfall of 166 mm in 60% of years (Read, 1995). Rainfall during the study period varied considerably with above average annual rainfall recorded in 1997 (240 mm), 2001 (263 mm) and

**Table 1**
The characteristics of reintroduced populations and their source populations. Two trial releases and 10 full-scale releases were conducted. Reintroductions in bold were deemed successful.

| Species | Year | Location of source population | Wild/captive bred | Climate of source population | Release location | Release pen | Release size (M.F) | No. radio-tracked |
|---|---|---|---|---|---|---|---|---|
| Greater stick-nest rat[a] | 1998 | Reevesby Island, S.A. | Wild | Mesic | Arid Recovery Reserve | Yes | 8(4.4) | 8 |
| Greater stick-nest rat | 1999 | Reevesby Is/Monarto Zoo, S.A | Wild/Captive Bred | Mesic | Arid Recovery Reserve | No | 92/6[c](55.43) | 30/6 |
| Burrowing bettong[a] | 1999 | Herisson Prong, W.A. | Wild | Semi-arid coastal | Arid Recovery Reserve | Yes | 10(3.7) | 10 |
| Burrowing bettong | 2000 | Bernier Island, W.A. | Wild | Semi-arid coastal | Arid Recovery Reserve | No | 20(8.12) | 10 |
| Greater bilby | 2000 | Monarto Zoo, S.A. | Captive Bred | Mesic[b] | Arid Recovery Reserve | Yes | 9(4.5) | 9 |
| Western barred bandicoot | 2001 | Bernier Island, W.A. | Wild | Semi-arid coastal | Arid Recovery Reserve | Yes | 12(2.10)[c] | 11 |
| Numbat | 2005 | Scotia Sanctuary, N.S.W. | Wild | Semi-arid inland | Arid Recovery Reserve | No | 5(3.2) | 5 |
| Woma python | 2007 | Zoos S.A. | Captive Bred | Mesic[b] | Arid Recovery Reserve | No | 9(7.2) | 9 |
| Greater bilby | 2004 | Arid Recovery | Wild | Arid | Wild West Zone | No | 12(8.6) | 12 |
| Greater bilby | 2007 | Arid Recovery | Wild | Arid | Wild West Zone | No | 20(7.13) | 20 |
| Burrowing bettong | 2008 | Arid Recovery | Wild | Arid | Wild West Zone | No | 101(58.43) | 15 |
| Burrowing bettong | 2008 | Arid Recovery | Wild | Arid | Red Lake Paddock | No | 66(40.26) | 0 |

(M.F.) = Sex ratio of released animals.
[a] Trial release.
[b] Original source stock from the arid deserts, captive breeding facilities located in mesic area near Adelaide.
[c] One female animal died before it could be released.

2004 (193 mm) and very dry conditions in 1999 (69 mm) and 2002 (44 mm). Rainfall in other years varied between 100 and 160 mm.

The dominant landforms within the three release areas are longitudinal orange sand dunes separated by clay interdunal swales. Dunes are generally spaced 100 m to 1 km apart. Three main habitat types are present; sandhill wattle (*Acacia ligulata*)/hopbush (*Dodonaea viscosa*) dunes, chenopod (*Atriplex vesicaria*)/(*Maireana astrotricha*) shrubland swales, and mulga (*Acacia aneura*) sandplains. Drainage is endoreic, into claypans and swamps.

The Roxby Downs region, has historically been used for sheep (*Ovis aries*) and cattle (*Bos taurus*) grazing. Stock damage is focused around artificial and natural waterpoints. Grazing ceased on the southern section of the Main Exclosure in the mid 1980s and the remaining sections of the Reserve were lightly grazed with negligible detectable influence on extant reptile and mammal capture rates (Read and Cunningham, 2010) until their gradual inclusion into the Reserve between 1999 and 2008.

### 2.2. Reintroductions

Museum records, literature, subfossil deposits (Owens and Read, 1999) and old nests and burrows were used to compile an inventory of the pre-European vertebrate fauna of the Roxby Downs region. Locally-extinct species were selected for reintroductions based on their previous distribution in the area and their availability. Translocation proposals were prepared and implemented for each species by Arid Recovery, a partnership between BHP Billiton, The University of Adelaide, the local community and The South Australian Department for Environment and Natural Resources (DENR). Proposals were approved by the DENR and where source populations were located in Western Australia, permission and export permits were also obtained from the Western Australian Department for Environment and Conservation.

Five IUCN-listed mammal species; the greater stick-nest rat (*Leporillus conditor*), the greater bilby (*Macrotis lagotis*), the burrowing bettong (*Bettongia lesueur*), the western barred bandicoot (*Perameles bougainville*) and the numbat (*Myrmecobius fasciatus*); and one IUCN-listed reptile species, the woma python (*Aspidites ramsayi*) were reintroduced to the Reserve between 1998 and 2001 (Table 1). Due to the limited numbers available for release, the greater bilbies and western barred bandicoots were released into a 10 ha release pen within the Main Exclosure where they were provided with supplementary food and water. After a few months, dispersal holes were cut in the sides of the release pen and animals allowed free access to the rest of the Main Exclosure. The numbats, although also constituting a small release size, were released directly into the Main Exclosure as they are termite specialists and roam over large areas to forage (Friend, 2008). Stick-nest rat and burrowing bettong releases occurred in two stages, a small trial release into the release pen with food and water provided followed by a full-scale release into the Main Exclosure a year later. Source populations were preferentially obtained from wild stocks (Table 1). Captive-bred individuals were descendants of wild individuals captured from the Franklin Islands (greater stick-nest rat) or Strzelecki Desert (woma python) in South Australia, or deserts in Western Australia and the Northern Territory (greater bilby). More detailed information on reintroduction protocols is available for the numbat (Bester and Rusten, 2009), woma python (Read et al., in press) and greater bilby (Moseby and O'Donnell, 2003).

One burrowing bettong reintroduction was attempted into the Red Lake Paddock in 2008 and involved a direct transfer of wild animals from the Main Exclosure without any supplementary food or water (Table 1). Two greater bilby and one burrowing bettong reintroduction attempts were made into the Wild West Zone between 2004 and 2008 (Table 1). Release animals were sourced from within the Reserve and released at a single location (Fig 1) with no supplementary food or water provided.

### 2.3. Monitoring

Both native and feral species were monitored using track counts at all three release locations. Within the Main Exclosure and the Red Lake Paddock, track counts involved walking along longitudinal sand dunes and recording animal tracks that crossed a 1 m wide path. To ensure consistency, an animal's track was counted each time it entered and left the path. Between 2000 and 2010, the number of tracks of greater stick-nest rat, greater bilby, burrowing bettong, western barred bandicoot and numbat were recorded along $8 \times 1$ km segments within the Main Exclosure between September and December each year. The presence or absence of tracks in each segment was also used to determine trajectories of distribution change within the Reserve since release. Between 2000 and 2005, the track transects were conducted on the morning after a windy day and a still night, to ensure only fresh tracks from a single night were counted. After 2005 the population of reintroduced species increased to the degree that it became necessary to clear old tracks the day prior to tracking by dragging a 1 m bar and chain behind a quadbike. Approximately 11 km of transect, divided into $3 \times 3$–4 km lengths, was also sampled in the Red Lake Paddock using this method from 2008 until 2010.

A subsample of all reintroduced species released into the Main Exclosure and Wild West Zone were monitored using radiotracking for at least 1 month after release (Table 1). After approximately 1 month, radiocollared animals were recaptured and weighed to determine weight loss. Cage trapping also occurred annually within the Main Exclosure and Red Lake Paddock to determine reproductive condition and record the presence of second generation individuals. Trapping was not used for density comparisons due to interspecific differences in trapability. Reintroduced species in the Wild West Zone were monitored using a combination of radiotracking, burrow monitoring and track counts along 50 km of dune crests on quad bike. Predator activity was also noted along these threatened species track transects which were located within 7 km of the release site (Fig. 1) and conducted monthly from January 2008 to March 2009.

Regional feral animal activity within the Wild West Zone was monitored using 45 short tracking segments which were sampled from 2003 to 2009. Segments were a modified version of the monitoring technique established by Engeman and Allen (2000) and each comprised a 200 m length of vehicle track on sandy substrate, separated by a distance of at least 500 m. Dingo tracks on successive segments were counted only once as the spacing was designed to be optimal for cat monitoring and dingoes often follow roads for several kilometres (Read and Eldridge, 2010). Segments were driven over by four wheel drive vehicle in the late afternoon on the

**Table 2**
Short, medium and long term criteria (numbered sequentially) used to determine reintroduction success.

| Criteria | Details |
|---|---|
| Short[1] | Survival of more than 50% of radiocollared individuals after 1 month |
| Short[2] | Weight loss less than 15% of body weight after 1 month |
| Short[3] | Independent young produced within 12 months |
| Medium[1] | Second generation produced within 2 years |
| Medium[2] | Increased distribution after 5 years |
| Medium[3] | Population extant after 8 years |
| Medium[4] | Population recovery after a drought event |
| Long[1] | Genetic diversity maintained |
| Long[2] | No significant loss of carrying capacity through intraspecific habitat alteration |
| Long[3] | Minimal intervention required for population regulation |

**Table 3**
The fate of 10 reintroduction events and 2 trial releases inside and outside the Arid Recovery Reserve including the presence or absence of feral species.

| Species | Year | Feral Species Present | | | Short Term Success Criteria | | | Medium Term Success Criteria | | | | Success | Reason for failure |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cat | Fox | Rabbit | 50% survival | <15% Weight loss | Indep. young | 2nd gen | Distribution | Extant 8 years | Drought recovery | | |
| Greater stick-nest rat[b] | 1998 | × | × | × | Yes | Yes | Yes | – | – | – | – | – | |
| Greater stick-nest rat | 1999 | × | × | × | Yes | No | Yes | Yes | Yes | Yes | Yes | YES | |
| Burrowing bettong[b] | 1999 | × | × | × | Yes | Yes | Yes | – | – | – | – | – | |
| Burrowing bettong | 2000 | × | × | × | Yes | Yes | Yes | Yes | Yes | Yes | Yes | YES | |
| Greater bilby | 2000 | × | × | × | Yes | No | Yes | Yes | Yes | Yes | Yes | YES | |
| Western b bandicoot | 2001 | × | × | × | Yes | Yes | Yes | Yes | Yes | Yes | Yes | YES | |
| Numbat | 2005 | × | × | × | Yes | No[a] | No | No | No | No | – | NO | Bird of prey predation |
| Woma python | 2007 | × | × | × | No | No[a] | No | No | No | No | – | NO | Mulga snake predation |
| Greater bilby | 2004 | √ | √ | √ | No | Yes | Yes | No | No | No | – | NO | Cat predation |
| Greater bilby | 2007 | √ | √ | √ | Yes | Yes | Yes | No | No | No | No | NO | Predation + drought |
| Burrowing bettong | 2008 | √ | √ | √ | Yes | No[a] | No | No[a] | No | No | No | NO | Predation |
| Burrowing bettong | 2008 | √ | × | √ | Yes | – | Yes | Yes | 3 to date | 3 to date | Yes | YES | |

[a] Animals lost more than 15% of body weight after 3 months rather than 1 month.
[b] These reintroductions were trial releases with full scale releases occurring within 12 months. Thus the medium term success criteria cannot be accurately determined for these trial release populations as their offspring cannot be distinguished from the full scale release.

day preceding sampling to obliterate older tracks and the following morning an observer walked each segment and recorded the presence or absence of fresh cat, fox, rabbit and dingo tracks on the vehicle track. Segments were pooled to determine the percentage with cat, fox and dingo presence and compared over time. Unfortunately this method could not be duplicated in the Red Lake Paddock due to insufficient lengths of vehicle tracks for adequate replication. Instead, feral animal tracks were counted along the 11 km of walking track transects used for monitoring burrowing bettongs.

### 2.4. Success criteria

We considered short, medium and long-term success criteria for reintroduction success (Table 2). Time lines for long-term success have not yet been met so only short and medium-term criteria are addressed here. An important medium-term criterion was the persistence and recovery of the population through drought, a common occurrence in the Australian arid zone that can cause widespread decline or local extinction in some mammal species (see Brandle and Moseby, 1999; Masters, 1993; Moseby et al., 2006). A drought is defined as a prolonged, abnormally dry period and is classified according to rainfall deficiencies over a certain period (Australian Bureau of Meteorology, 2011). Severe rainfall deficiency periods of 12 months or more, when rainfall was among the lowest 5% on record, were used to determine the start and end of drought conditions at Olympic Dam (10–15 km from the reintroduction sites) between 1998 and 2010.

Sutherland et al. (2010) outlined recommendations for monitoring and documenting bird reintroductions. Where appropriate, we also recorded these details for our mammal and reptile reintroductions (Table 1).

## 3. Results

Two drought periods were identified in the 12 years between 1998 and 2010 based on severe rainfall deficiencies, a 12 month deficiency from January 2002 to January 2003 when only 43 mm of rain were recorded for the period (average of 3.3 mm per month) and an 18 month deficiency from May 2007 to October 2008 when 74 mm of rain was recorded (average of 4 mm per month).

### 3.1. Main exclosure reintroductions

No cats or foxes were detected in the Main Exclosure during this study. The releases of 106 greater stick-nest rats, 30 burrowing bettongs, nine greater bilbies and 12 western barred bandicoots were all successful and populations fluctuated over time but generally increased (Moseby and O'Donnell, 2003; Moseby and Bice, 2004; Fig. 5). Only one of 157 translocated animals died in transit (a wild sourced stick-nest rat) and one female western barred bandicoot died during a vet check just prior to release. The only deaths in the first few weeks after release were two captive-bred and four wild sourced stick-nest rats. All these deaths were thought to have been due to stress-related trauma. A minimum of two of the three short-term criteria were met with significant weight loss recorded initially in some species but more than 50% of released animals survived the first month and reproduction occurred within 12 months (Table 3). One male bilby and one female stick-nest rat both lost more than 15% of body weight but went on to regain the weight after four to 5 months. When medium-term criteria were considered, second generation individuals were produced and all four species increased their distribution within the Arid Recovery Reserve in the 5 years after

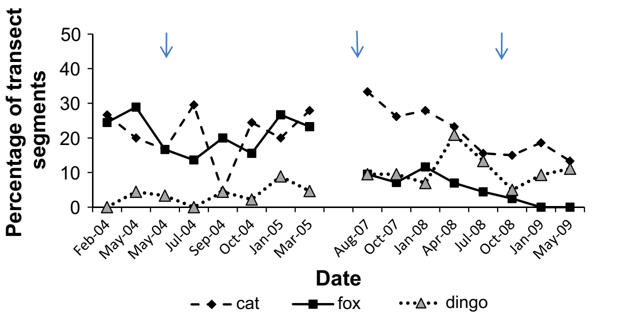


**Fig. 2.** Predator activity outside the Reserve in the Wild West Zone between 2004 and 2009. Arrows indicate timing of Wild West reintroduction attempts. Total number of segments is 45.

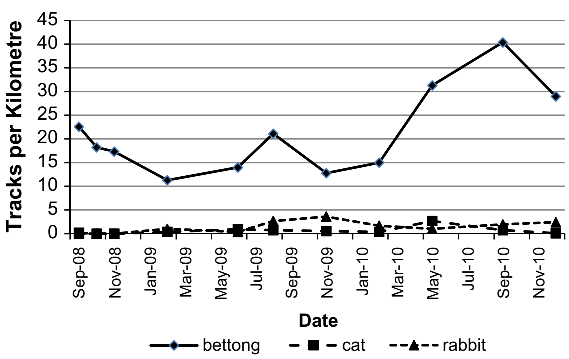


**Fig. 3.** Track activity of burrowing bettongs, rabbits and feral cats within the Red Lake Paddock area after bettongs were released in September 2008. Total transect length is 11 km.

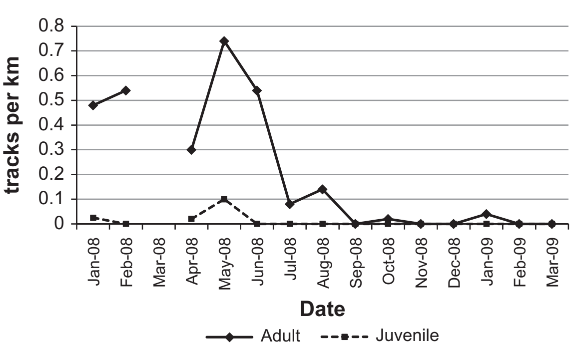


**Fig. 4.** Track activity of reintroduced greater bilbies in the Wild West Zone after their release in August 2007. Track monitoring did not begin until January 2008 after tail radiotransmitters were removed. Total transect length is 50 km.

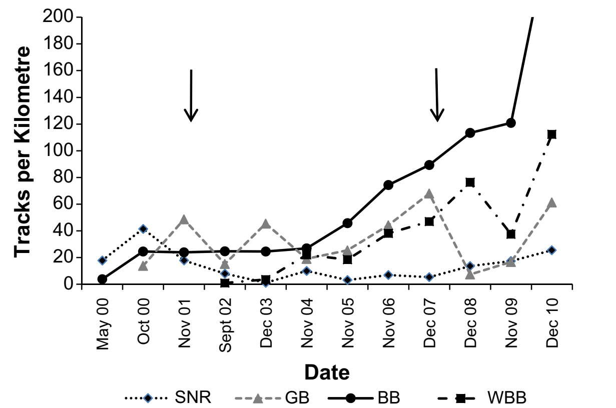


**Fig. 5.** Annual activity counts for four species reintroduced into the Main Exclosure of Arid Recovery. The total length of transects is 8 km. December 2010 bettong track counts exceeded 200 but the axis scale was reduced to show trends for other species. Arrows indicate drought events.

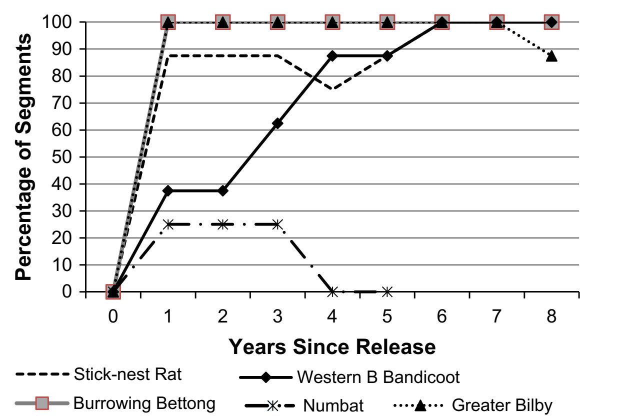


**Fig. 6.** The increase in distribution of reintroduced species in the Main Exclosure of the Arid Recovery Reserve after release. Distribution is shown as the percentage of track transect segments with tracks present. Total transect segments is 8 ($8 \times 1$ km).

release (Fig. 6). Stick-nest rat, burrowing bettong and greater bilby tracks were recorded on more than 75% of track transect segments within 1 year of release (Fig. 6) and their nests and burrows were observed in all segments within 3 years. Western barred bandicoots took longer to colonise the Reserve but were present in nearly 90% of segments within 4 years.

All four species met the third medium-term reintroduction criterion of being extant within the Reserve 8 years after release (Table 3). Population recovery after drought, the important fourth success criterion, was tested during the droughts of 2002 and 2008. Track counts of bilby and stick-nest rat declined by 50% during the 2002 drought and both western barred bandicoot and bilby tracks declined by more than 50% during the 2008 drought. All populations recovered and began increasing within 2 years of the droughts breaking (Fig. 5). Burrowing bettong tracks did not decline during either drought event.

The numbat and woma python releases into the Arid Recovery Reserve were both unsuccessful with reintroduced animals killed by native predators. The numbat release met no medium-term success criteria and only one of the short-term criterion, namely 50% of released animals were still alive 1 month after release. Of the five numbats released, one male and two females were killed by bird of prey at 47 days and 7 months after release respectively (Bester and Rusten, 2009). The other two male numbats, including one that temporarily lost more than 25% of its body weight after release, were recorded on track transects up until 3 years after release. All of the reintroduced woma pythons were killed within 4 months, with mulga snake (*Pseudechis australis*) predation confirmed or implied in all cases (Read et al., in press). This predation occurred despite raising the pythons to 5 years of age (mean snout-vent length 1312 ± SE 58 mm, mean weight 1032 ± SE 140 g) before release, so that they were only slightly smaller than the mulga snakes that killed them. No short-term success criteria were met, more than 50% were dead within 1 month of release, no breeding occurred and significant weight loss was recorded. We were not able to recapture woma pythons after 1 month as they were sheltering in burrowing bettong warrens but when two snakes were opportunistically recaptured at 77 days and 112 days after release they had lost 24% and 27% of their body weight respectively.

However, none of the pythons appeared emaciated or unhealthy whenever they were observed directly during the trial and successful feeding was confirmed for one python, which contained substantial fat bodies during necropsy following its death 101 days after release (Read et al., in press).

### 3.2. Red Lake reintroduction

No foxes were recorded within the Red Lake Paddock during the study and cat activity ranged from zero to one track intercept per kilometre during 2008 and 2009, increasing to three per kilometre in 2010 (Fig. 3). Rabbit track activity was low with less than five tracks per kilometre recorded (Fig. 3). The release of 66 burrowing bettongs in September 2008 was deemed successful based on both short-term and medium-term success criteria (Table 3). Track monitoring indicated that activity remained stable after release suggesting that less than 50% of individuals died in the first month and the first success criterion was met (Fig. 3). Track activity mirrored that recorded inside the Main Exclosure in the first few years after release, with activity gradually increasing (Figs. 3 and 5). Trapping 1 year after release recorded untagged animals that had been recruited into the population, several with their own pouch young. Bettong tracks and burrows were recorded on all three track transect segments within 1 year of release indicating that they had increased their distribution and met the third medium-term success criterion. Although animals were released during the drought of 2008, the bettong population increased after the drought, thereby satisfying the last medium-term success criterion.

### 3.3. Wild West reintroductions

All three reintroduction attempts into the unfenced Wild West Zone were unsuccessful despite meeting some short-term success criteria. During the first greater bilby release in June 2004, seven out of the 12 bilbies died within 25 days of release, contravening the first short-term success criterion (Table 3). Predation was the only confirmed cause of death with six deaths from feral cats and one from an unknown predator. Cat tracks were observed around fresh carcasses, some cats were captured at cached remains, and one cat trapped in the area had bilby remains in its stomach. The other two short-term criteria were met, four bilbies that were still alive 3 months after release had maintained or increased their weight and at least three juvenile bilbies were known to survive to pouch exit. Another adult bilby was killed by a cat 8 months after release and a population of bilbies outside the Reserve failed to become established. Bilbies exhibited high site fidelity with all females and most males remaining within 2 km of the release site. Cat and fox tracks were recorded on 30 and 14% of regional track segments in the Wild West Zone one month after the reintroduction (Fig. 2) and cat tracks were commonly observed in the release area. Dingo activity was recorded on less than 10% of track segments and tracks were never observed within 4 km of the release site.

During the second Wild West Zone bilby release in August 2007, bilbies exhibited high site fidelity and persisted for longer. All three short-term criteria were met and only two of the 20 released bilbies died in the first month, one from suspected malnutrition and one from predation by a wedge-tailed eagle. A cat killed a third bilby at 4 months post-release. Track counts of the released adult population of bilbies remained relatively stable in the Wild West Zone for 12 months after release until July 2008 when there was a significant decline (Fig. 4). Juvenile bilby tracks were first recorded along track transects 5 months after release and peaked in May 2008 after which time no juvenile tracks were recorded (Fig. 4). Juvenile tracks were followed to burrows where fresh cat tracks were always observed around the entrance. The last adult bilby track was observed 19 months after initial release in January 2009 and the release did not meet any medium-term success criteria (Table 3). All females and four of the seven male bilbies remained within 4 km of the release site and cat and occasionally fox tracks were recorded during monthly threatened species track counts in this area. On the regional feral track segments, cat activity was three times higher than fox or dingo during the first 5 months after release (25–35% of segments) before declining to 15% in July 2008 (Fig. 2). There was a simultaneous decline in bilby, rabbit and predator activity that corresponded with an intensification of drought conditions, suggesting increased predation pressure from a declining cat and fox population under nutritional stress. Despite their regional occurrence (Fig. 2), dingoes were not implicated in the deaths of any bilbies as they were not recorded within 4 km of the release site on monthly threatened species track counts until November 2008, several months after the bilby decline.

One hundred and one burrowing bettongs were released into the Wild West Zone in September 2008. Fourteen of the 15 radiocollared bettongs died within 4 months of release and no animals were known to be alive at 7 months post-release (March 2009). Four radiocollared bettongs and 10 uncollared bettongs were killed at the release site within 24 h of release. Track identification and post mortem analysis by Zoos S.A. revealed that the cause of death in all these cases was a dingo or wild dog. Only one short-term success criterion was met, less than 50% mortality in the first month. Some recaptured bettongs had lost more than 15% of their body weight but this weight loss was also recorded inside the Reserve during the same period. Small pouch young were observed at 3 months post-release but no independent young were recorded. Fifty four rabbit warrens within the Wild West Zone showed signs of bettong occupancy at 1 month after release, declining to zero at 7 months post-release. Seven cat, two dingo and one fox track were observed at monitored warrens.

Six of the 15 radiocollared bettongs left the Wild West Zone and travelled up to 18 km away into areas where predators were not controlled. When retrieved, their bodies were too decomposed for autopsy but predation was considered the cause of death because radiocollars showed signs of predator damage; misshapen metal collar bands, teeth puncture marks in the rubber surrounding the metal collar and/or fur stuck to the band. These long distance movements out of the Wild West Zone are likely to have permitted increased predation rates probably from cats and foxes, as dingoes are rarely recorded south of the dingo fence where the dispersed bettongs were found. Cat tracks were present on two to three times more track segments than both fox and dingo tracks during the first 4 months after release (Fig. 2).

## 4. Discussion

Half of the 10 reintroduction events were unsuccessful with predation the key factor responsible for reintroduction failure. Native predators were responsible for two failures inside the Reserve and cat activity levels outside the Reserve were apparently too high for successful reintroductions of bilbies in this area. Predation from cat, foxes and dingoes was thought to be responsible for the failure of the burrowing bettong release outside the Reserve. Predation has been responsible for the failure of many global reintroduction programs (Fischer and Lindenmayer, 2000), and 80% of mammal reintroduction failures in Australia are attributed to predation (Short, 2009). Other greater bilby reintroductions have been successful in Australia only where cats and foxes have been excluded, with failed reintroduction attempts into unfenced arid areas also attributed to predation (Christensen and Burrows, 1994; Southgate, 1994; Southgate and Possingham, 1995).

Reintroduced greater bilbies survived significantly longer than burrowing bettongs outside the Reserve in the presence of exotic predators. Elsewhere, Southgate and Possingham (1995) also found some adult bilby individuals alive 28 months after reintroduction into Watarrka National Park in northern Australia where introduced predators were present. These results, coupled with our observation that juvenile bilbies were not surviving, suggest that whilst adult bilbies may tolerate some level of feral predator presence, juveniles may be particularly vulnerable to cat predation. Other studies suggest that cats may impact threatened species such as burrowing bettongs (Short and Turner, 2000) and black flanked rock wallabies (Read and Ward, 2010) through their predation on juveniles.

There is some evidence that drought may be a particularly vulnerable time for reintroduced populations when exotic predators are present. Reintroduced populations of the greater bilby and burrowing bettong both inside and outside the Reserve suffered from population decline or weight loss during the drought in 2008, but only outside populations became extinct. The dry conditions and subsequent decline in rabbit activity may have precipitated prey switching, resulting in increased predation pressure on reintroduced populations. Drought also likely lowered reproductive rates, increasing the susceptibility of the population to predator-driven extinction.

Interestingly, the bettong reintroduction into the Red Lake Paddock in the presence of very few cats has met most medium-term success criteria. The absence of foxes in this paddock is likely to have contributed to reintroduction success and evidence from other studies suggest that in some cases, only a proportion of cats are able, or inclined, to be significant predators of certain prey species (Spencer, 1991). The reintroduced western barred bandicoot at Herisson Prong in Western Australia was able to successfully establish in the presence of one cat per 4–6 $km^2$ but at significantly lower densities than cat-free islands (Richards and Short, 2003). Future monitoring will determine whether bettong densities reach those recorded in predator-free areas of the Reserve.

The killing of 17 burrowing bettongs by a single dingo on the night of release outside the Reserve implies that surplus killing by dingoes may also represent a threat to some reintroductions. The first few hours after release are arguably the time when predator-naive animals are most susceptible to surplus killing and it is not known what impact the dingo may have had on an established population.

Improved control of exotic predators, particularly cats, is needed before broadscale reintroductions into unfenced arid areas are likely to be successful. Determining thresholds of predator activity below which successful reintroduction of threatened species can occur are urgently needed to improve the science of reintroduction biology in Australia. Predator thresholds are likely to vary according to species, season, habitat and alternative prey abundance and so require a national experimental approach including standards for measuring terrestrial predator abundance. This would enable results from reintroduction attempts to be more widely comparable and allow for increased hypothesis testing in future releases. Thresholds, together with the development of broadscale predator control methods, should form the basis for threatened species recovery in Australia over the next decade.

Apart from predation, other factors had no obvious impact on reintroduction success. Our findings supported work by Short (2009) who found no correlation between reintroduction success and source populations in Australia in comparison to Fischer and Lindenmayer (2000) who reported higher reintroduction success by global practitioners who used wild stock. We also used a one way ANOVA to compare releases size in successful and unsuccessful reintroductions but found no significant difference. The majority of bird and mammal reintroductions in Australia and overseas between 1973 and 1986 comprised less than 75 animals (Griffith et al., 1989) and whilst many studies have found larger release groups more successful (Griffith et al., 1989; Wolf et al., 1998; Fischer and Lindenmayer, 2000), smaller groups have had a higher success rate in Australia (Short, 2009). However, the covariate influence of introduced predators on the success of small or captive-bred release groups has not been investigated. The majority of successful Australian mammal reintroductions with small or captive-bred founders have been into predator-free environments (see Richards and Short, 2003; Finlayson et al., 2008; present study). When exotic predators are present, large release groups (see Sinclair et al., 1998) and wild source populations may be imperative. In our study, the relatively large release size of 67 bettongs into the Red Lake Paddock where cats were present may have been integral in securing the success of this release.

The low abundance of rabbits in the Red Lake Paddock and absence of rabbits in the Main Exclosure may have contributed to the success of reintroductions in these areas. Reintroductions into areas where rabbits are present have been successful (Richards and Short, 2003; Currawinya Reserve Queensland, Peter McRae pers. comm.) but removing or controlling exotic predators can lead to significant increases in rabbit numbers (Newsome et al., 1989; Robley et al., 2002). Rabbits can cause severe vegetation damage (Lange and Graham, 1983) and Richards and Short (2003) found litter size in reintroduced western barred bandicoots increased with a decrease in rabbit abundance. However, Robley et al. (2002) found no influence of rabbits on the survival, recruitment or rate of increase of reintroduced burrowing bettongs. The main threat to reintroduced species from rabbits appears to be the secondary influence of sustaining higher predator numbers which in turn prey on native species, especially as rabbit numbers decline in drought conditions.

The use of a release pen did not improve medium-term reintroduction success within the Reserve but may have assisted with the welfare of individuals during the early stages of release. Release pens may be more useful in areas where predators are present as they allow competitors and both exotic and native predators to be removed (Richards and Short, 2003). In large release areas, pens may also be useful for preventing hyperdispersal after release (Short and Turner, 2000), a problem encountered with our external bettong release and in some other reintroduction programs (Christensen and Burrows, 1994; Short and Turner, 2000; Flinders Ranges National Park, Peter Copley pers. obs.). Males that disperse large distances from the release site are unlikely to contribute to the population and may be at higher risk of predation (Steen, 1994; Norrdahl and Korpimaki, 1998; Anthony and Blumstein, 2000).

Reintroducing species from non-arid areas did not appear to affect the success of reintroductions suggesting that local extinction of arid-adapted populations may not be an impediment to re-establishment in arid areas. Poor habitat quality has hampered other reintroduction attempts (Griffith et al., 1989; Wolf et al., 1998) but despite high historical rabbit abundance in the Arid Recovery region (Bowen and Read, 1998), habitat quality appeared sufficient to support breeding populations of two primarily herbivorous species, the stick-nest rat and burrowing bettong.

The failure of the woma reintroduction through predation by mulga snakes was not predicted prior to release; woma pythons are known predators of elapid snakes, they were nearly as large as adult mulga snakes when released and high densities of mulga snakes had not been recorded within the Reserve. This failed reintroduction attempt reinforces the benefits of closely monitoring releases, particularly when the ecology, behaviour and abundance of the reintroduced species and extant in situ species are not thoroughly understood.

In general, short-term criteria such as weight loss and production of independent young were not accurate predictors of medium-term reintroduction success with nine out of 10 releases meeting at least one short-term success criterion but only five meeting medium-term criteria (Table 3). Short-term criteria may be useful as early health indicators for triggering management interventions and provide initial insight into habitat quality and the success of any predator control activities. In arid areas, medium-term criteria should include the ability to recover from drought events as these are times of low reproductive output when species are arguably most vulnerable to predation and local extinction. Criteria referring to pre-defined population increases are less relevant since many arid zone species exhibit large fluctuations in abundance depending on seasonal conditions (Newsome and Corbett, 1975; Dickman et al., 1999).

Seddon (1999) states that the ultimate objective of any reintroduction is "population persistence without intervention" but concedes that this is unrealistic in many cases. Exclosure fences require ongoing maintenance, predator incursions must be addressed and monitoring should continue indefinitely. We have attempted to minimise the need for intervention by increasing the size of the Arid Recovery Reserve to 123 $km^2$ in order to accommodate large populations. Larger Reserve area and population size will improve genetic viability, possibly allow low levels of predator incursions to be tolerated and increase the chance of intercepting patchy rainfall events to reduce drought impacts. Other long-term success criteria include no significant loss of carrying capacity through intraspecific habitat alteration, a criterion developed after burrowing bettongs reached high densities and began affecting vegetation within the Reserve. Ideally, the reintroduced population should not inadvertently cause their own decline through actions such as overbrowsing. Continued attempts to reintroduce native predators will hopefully lead to a self-sustaining ecosystem where minimal intervention is required.

## Acknowledgements

Arid Recovery is a conservation initiative supported by BHP Billiton, The University of Adelaide, The South Australian Department for Environment and Natural Resources and the local community. Funding for this project was generously provided by the Nature Foundation, WWF Threatened Species Network, The Australian Federal Government's Natural Heritage Trust and Envirofund, BHP Billiton, the Wildlife Conservation Fund and Australian Geographic. Other organisations such as Zoos S.A, Western Australian Department for Environment and Conservation and the Australian Wildlife Conservancy provided considerable in kind support. We are indebted to the many Arid Recovery staff and volunteers who assisted with the project including Adam Bester, Jackie Bice, Judith Carter, Laura Cunningham, Melissa Farrelly, Andrew Freeman, Bree Galbraith, Travis Gotch, Steve Green, Greg Kammermann, Nicki Munro, Karl Newport, Katie Oxenham, Pete Paisley, Cara Reece, Karen Rusten, Justine Smith, Jenny Stott, Clint Taylor and Jeff Turpin. Thanks to Adam Bester for persevering with suggestions for improving the track monitoring transect methodology and for coordinating the numbat release. Melissa Farrelly and Clint Taylor coordinated the feral animal control during the Wild West Releases. Reintroductions were conducted under ethics approval from the South Australian Wildlife Ethics Committee, Approval Numbers 42/2005, 6/2005, 19/2000, 22/99, 18/2000, 27/98, 4/99 and 2/2000.

## References

Anthony, L.L., Blumstein, D.T., 2000. Integrating behaviour into wildlife conservation: the multiple ways that behaviour can reduce $N_e$. Biol. Conserv. 95, 303–315.

Australian Bureau of Meteorology, 2011. Australian Bureau of Meteorology Website. <http://www.bom.gov.au>.

Backhouse, G.N., Clark, T.W., Reading, R.P., 1994. Reintroductions for recovery of the eastern barred bandicoot *Perameles gunnii* in Victoria, Australia. In: Serena, M. (Ed.), Reintroduction Biology of Australian and New Zealand Fauna. Surrey Beatty and Sons, Chipping Norton, NSW, pp. 209–218.

Bajomi, B., 2010. Reintroduction of Endangered Animal Species: Complementing the IUCN Guidelines. Review Protocol. Centre for Environmental Science, Eötvös Loránd University of Sciences, Budapest, Hungary, pp. 10. <http://www.environmentalevidence.org/Documents/Draftprotocol86.pdf> (accessed 16.02.11)

Beck, B.B., Rapaport, L.G., Stanley-Price, M.R., Wilson, A.C., 1994. Reintroduction of captive-born animals. In: Olney, P.J.S., Mace, G.M., Feister, A.T.C. (Eds.), Creative Conservation: Interactive Management of Wild and Captive Animals. Chapman & Hall, London, pp. 265–286.

Bester, A.J., Rusten, K., 2009. Trial translocation of the numbat (*Myrmecobius fasciatus*). Aust. Mammal. 31, 9–16.

Bowen, Z.E., Read, J.L., 1998. Population and demographic patterns of rabbits (*Oryctolagus cuniculus*) at Roxby Downs in arid South Australia and the influence or rabbit haemorrhagic disease. Wildlife Res. 25, 655–662.

Brandle, R., Moseby, K.E., 1999. Comparative ecology of two populations of *Pseudomys australis* in northern South Australia. Wildlife Res. 26, 541–564.

Christensen, P., Burrows, N., 1994. Project desert dreaming: experimental reintroduction of mammals to the Gibson Desert, Western Australia. In: Serena, M. (Ed.), Reintroduction Biology of Australian and New Zealand Fauna. Surrey Beatty & Sons, Sydney, Australia, pp. 199–207.

Dickman, C.R., Mahon, P.S., Masters, P., Gibson, D.F., 1999. Long-term dynamics of rodent populations in arid Australia: the influence of rainfall. Wildlife Res. 26, 389–403.

Dodd, C.K., Seigel, R.A., 1991. Relocation, repatriation and translocation of amphibians and reptiles: are they strategies that work? Herpetologica 47, 336–350.

Engeman, R.M., Allen, L., 2000. Overview of a passive tracking index for monitoring wild canids and associated species. Integr. Pest Manage. Rev. 5, 197–203.

Finlayson, H.H., 1941. On central Australian mammals. Part III. The Muridae. Trans. Roy. Soc. South Aust. 65, 215–231.

Finlayson, H.H., 1961. On central Australian mammals, Part IV. The distribution and status of central Australian species. Recs. South Aust. Mus. 14, 141–191.

Finlayson, G.R., Viera, E.M., Priddel, D., Wheeler, R., Bentley, J., Dickman, C.R., 2008. Multi-scale patterns of habitat use by re-introduced mammals: a case study using medium-sized marsupials. Biol. Conserv. 141, 320–331.

Fischer, J., Lindenmayer, D.B., 2000. An assessment of the published results of animal relocations. Biol. Conserv. 96, 1–11.

Friedel, M.H., 1985. The population structure and density of central Australian trees and shrubs, and relationships to range condition, rabbit abundance and soil. Aust. Rangeland J. 7, 130–139.

Friend, J.A., 2008. Numbat (*Myrmecobius fasciatus*). In: Van Dyck, S., Strahan, R. (Eds.), The Mammals of Australia. Reed New Holland, Australia, pp. 162–165.

Gibson, D.F., Johnson, K.A., Langford, D.G., Cole, J.R., Clarke, D.E., Community, Willowra., 1994. The Rufous Hare-wallaby *Lagorchestes hirsutus*: a history of experimental reintroduction in the Tanami Desert, Northern Territory. In: Serena, M. (Ed.), Reintroduction Biology of Australian and New Zealand Fauna. Surrey Beatty and Sons, Chipping Norton, NSW, pp. 171–176.

Griffith, B., Scott, J.M., Carpenter, J.W., Reed, C., 1989. Translocation as a species conservation tool: status and strategy. Science 245, 477–480.

IUCN, 1998. Guidelines for Re-introductions. Prepared by IUCN/SSC Reintroduction Specialist Group. IUCN, Gland, Switzerland.

Lange, R.T., Graham, C.R., 1983. Rabbits and the failure of regeneration in Australian arid zone *Acacia*. Aust. J. Ecol. 8, 377–381.

Masters, P., 1993. The effects of fire-driven succession and rainfall on small mammals in spinifex grassland at Uluru National Park, Northern Territory. Wildlife Res. 20, 803–813.

Morton, S.R., 1990. The impact of European settlement on the vertebrate animals of arid Australia: a conceptual model. Proc. Ecol. Soc. Aust. 16, 201–213.

Moseby, K.E., Bice, J., 2004. A trial reintroduction of the Greater Stick-nest Rat (*Leporillus conditor*) in arid South Australia. Ecol. Manage. Rest. 5, 118–124.

Moseby, K.E., O'Donnell, E., 2003. Reintroduction of the greater bilby, *Macrotis lagotis* (Reid) (Marsupialia: Thylacomyidae), to northern South Australia: survival, ecology and notes on reintroduction protocols. Wildlife Res. 30, 15–27.

Moseby, K.E., Read, J.L., 2006. The efficacy of feral cat, fox and rabbit exclusion fence designs for threatened species protection. Biol. Conserv. 127, 429–437.

Moseby, K.E., Owens, H., Brandle, R., Bice, J.K., Gates, J., 2006. Variation in population dynamics and movement patterns between two geographically isolated populations of the dusky hopping mouse (*Notomys fuscus*). Wildlife Res. 33, 222–232.

Newsome, A.E., Corbett, L.K., 1975. Outbreaks of rodents in semi-arid and arid Australia: causes, preventions, and evolutionary considerations. In: Prakash, I., Ghosh, P.K. (Eds.), Rodents and Desert Environments. Junk, The Hague, Netherlands, pp. 117–153.

Newsome, A.E., Parer, I., Catling, P.C., 1989. Prolonged prey suppression by carnivores – predator-removal experiments. Oecologia 78, 458–467.

Norrdahl, K., Korpimaki, E., 1998. Does mobility or sex of voles affect risk of predation by mammalian predators? Ecology 79, 226–232.

Owens, H.M., Read, J.L., 1999. Mammals of the Lake Eyre South region. Vol. 1, Part 2. In: Slater, W.J.H. (Ed.), Lake Eyre South Monograph Series. RGSSA, Adelaide.

Priddel, D., Wheeler, R., 1997. Efficacy of fox control in reducing the mortality of released captive-reared Malleefowl, *Leipoa ocellata*. Wildlife Res. 24, 469–482.
Priddel, D., Wheeler, R., 2002. An Experimental Translocation of Brush-tailed Bettongs *Bettongia penicillata* to western New South Wales. Department of Conservation and Environment, Hurtsville, NSW, Australia.
Read, J.L., 1995. Recruitment characteristics of the White Cypress Pine (*Callitris glaucophylla*) in arid South Australia. Rangeland J. 17, 228–240.
Read, J.L., Cunningham, R., 2010. Relative impacts of cattle grazing and feral animals on an Australian arid zone reptile and small mammal assemblage. Aust. Ecol. 35, 314–324.
Read, J.L., Eldridge, S., 2010. An optimised rapid detection technique for simultaneously monitoring activity of rabbits, cats, foxes and dingoes in the rangelands. Rangeland J. 32, 389–394.
Read, J., Ward, M.J., 2010. Warru Recovery Plan – Recovery of *Petrogale lateralis* MacDonnell Ranges Race in South Australia. Warru Recovery Team, South Australia, DENR, Adelaide.
Read, J.L., Johnston, G.R., Morley, T.P., in press. Snake predation thwarts trial reintroduction of threatened woma pythons, *Aspidites ramsayi.* Oryx.
Read, J.L., Moseby, K.E., Briffa, J., Kilpatrick, A.D., Freeman, A., 2011. Eradication of rabbits from landscape scale exclosures: pipedream or possibility? Ecol. Manage. Rest. 12, 46–53.
Richards, J.D., Short, J., 2003. Reintroduction and establishment of the western barred bandicoot *Perameles bougainville* (Marsupialia: Peramelidae) at Shark Bay, Western Australia. Biol. Conserv. 109, 181–195.
Robley, A.J., Short, J., Bradley, S., 2002. Do European rabbits (*Oryctolagus cuniculus*) influence the population ecology of the Burrowing Bettong (*Bettongia lesueur*)? Wildlife Res. 29, 423–429.
Sarrazin, F., Barbault, R., 1996. Reintroduction: challenges and lessons for basic ecology. Trends Ecol. Evol. 11, 474–478.
Seddon, P.J., 1999. Persistence without intervention: assessing success in wildlife reintroductions. Trends Ecol. Evol. 14, 503.
Seddon, P.J., Armstrong, D.P., Maloney, R.F., 2007. Developing the science of reintroduction biology. Conserv. Biol. 21, 303–312.
Short, J., 2009. The Characteristics and Success of Vertebrate Translocations within Australia. Australian Government Department of Agriculture, Fisheries and Forestry, Canberra.
Short, J., Turner, B., 2000. Reintroduction of the burrowing bettong *Bettongia lesueur* (Marsupialia: Potoroidae) to mainland Australia. Biol. Conserv. 96, 185–196.
Short, J., Bradshaw, S.D., Giles, J., Prince, R.I.T., Wilson, G.R., 1992. Reintroduction of macropods (Marsupialia: Macropodoidea) in Australia: a review. Biol. Conserv. 62, 189–204.
Sinclair, A.R.E., Pech, R.P., Dickman, C.R., Hik, D., Mahon, P., Newsome, A.E., 1998. Predicting effects of predation on conservation of endangered prey. Conserv. Biol. 12, 564–575.
Soorae, P.S., 2010. Global Re-introduction Perspectives: 2010. Additional Case-studies from Around the Globe. IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE.
Southgate, R., 1994. Why reintroduce the Bilby? In: Serena, M. (Ed.), Reintroduction Biology of Australian and New Zealand Fauna. Surrey Beatty & Sons, Chipping Norton, pp. 165–170.
Southgate, R., Possingham, H., 1995. Modelling the reintroduction of the greater bilby *Macrotis lagotis* using the metapopulation model Analysis of the Likelihood of Extinction. Biol. Conserv. 73, 151–160.
Spencer, P.B.S., 1991. Evidence of predation by a feral cat, *Felis catus* (Carnivora: Felidae) on an isolated rock-wallaby colony in tropical Queensland. Aust. Mammal. 14, 143–144.
Steen, H., 1994. Low survival of long distance dispersers of the root vole (*Microtus oeconomus*). Ann. Zool. Fennici 31, 271–274.
Sutherland, W.J., Armstrong, D., Butchart, S.H.M., Earnhardt, J.M., Ewen, J., Jamieson, I., Jones, C.G., Lee, R., Newbery, P., Nichols, J.D., Parker, K.A., Sarrazin, F., Seddon, P.J., Shah, N., Tatayah, V., 2010. Standards for documenting and monitoring bird reintroduction projects. Conserv. Lett. 3, 229–235.
Vale, T., Schmitz, A., Fogarty, P., Bentley, J., 2004. Translocation Proposal for the Reintroduction of the Burrowing Bettong or Boodie (*Bettongia lesueur*) to Yookamurra Sanctuary, Murraylands South Australia. Australia.
Wilson, A.D., 1990. The effect of grazing on Australian ecosystems. In: Saunders, D.A., Hopkins, A.J.M., How, R.A. (Eds.), Australian Ecosystems: 200 Years of Utilization, Degradation and Reconstruction. Proceedings of the Ecological Society of Australia. Surrey Beatty and Sons, Chipping Norton, Australia, pp. 235–244.
Wolf, C.M., Garland, T.J., Griffith, B., 1998. Predictors of avian and mammalian translocation success: reanalysis with phylogenetically independent contrasts. Biol. Conserv. 86, 243–255.