Reintroduction of the Brush-tailed Bettong (*Bettongia penicillata ogilbyi*) into Lincoln National Park

Program review from September 1999 to July 2004

Sheridan Martin, Stephen Ball and Paula Peeters

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Cover photos: Joe Tilley holding Brush-tailed Bettong prior to release (Michael Freak), Mallee habitat near release area in Lincoln National Park (Amy Ide).

Government of South Australia

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ArcGis* (Geog. Information System) program was used to create the bettong distribution maps. Data was sourced by DEH regional conservation and adapted by Steve Ball, contract GIS support.

1. Executive Summary

A program to reintroduce the Brush-tailed Bettong *(Bettongia penicillata ogilbyi)* to Lincoln National Park (LNP), South Australia, was initiated in September 1999 as part of a regional restoration program on Lower Eyre Peninsula. This was the second attempt to reintroduce this species to a mainland location in South Australia without predator control fencing. An intensive fox baiting program began in LNP in 1997, with additional predator and rabbit control undertaken several months prior to bettong release events. A total of one hundred and thirteen bettongs were released between September 1999 and April 2001. Bettongs were sourced from Venus Bay Conservation Park (VBCP) for four of the releases, and were sourced from St. Peters Island (SPI) for one of the releases. Fifty-four bettongs were monitored by radio telemetry between September 1999 and November 2003. Five permanent trapping transects were established to monitor the spread of bettongs through the park over time. Trapping was also undertaken to check on the health of radio-tracked bettongs and to adjust or replace collars.

Only one of 113 bettongs did not survive relocation, and bettongs trapped after release were consistently in good condition. Signs of reproduction were frequently observed, with 85 % of females trapped between 1999 and 2004 carrying pouch young, and at least 36 locally-born bettongs recorded independent of their mothers by May 2004.
Mean survivorship probability of the monitored bettongs was very high in the first twelve months, yet dropped dramatically the second year. Survivorship probability increased in the third year, but not to the high level of year one. This is consistent with observations that the population stabilised after a number of peaks in mortality followed by concentrated predator control. Cat teeth marks found on collars indicated that many deaths (48 %) may have been caused by feral cats. At the time of writing, a small breeding population of bettongs survives in Lincoln National Park and this is the only South Australian mainland population of Brush-tailed Bettongs outside of predator-proof area.

Nonetheless, the population in Lincoln National Park appears to be declining, and management action is needed to ensure that it does not become extinct. Ongoing cat and fox control appears to be essential to maintain the population in LNP under current habitat conditions. However, the vegetation of LNP has been highly modified since European settlement, including the alteration of fire regimes, and currently experiences high grazing pressure from kangaroos and rabbits. This is likely to have reduced the amount and quality of food resources available to bettongs, which would increase the time that bettongs spend foraging for food, and thus increases their vulnerability to predators. Therefore reduction of grazing pressure, and the use of fire to maintain suitable habitat, are also likely to be essential for the survival of bettongs in LNP, especially if effective cat control is not achievable.

Additional releases may be necessary to counter low bettong densities and limited spread throughout the park and to answer some of the questions raised by this release.
Analysis of radio tracking data indicates that at least 10 and ideally 20 monitored bettongs are needed to provide minimum data for analysis, and that a large sample size is more important than a high frequency of monitoring events to estimate survivorship probability. Whip-style radio collars are recommended for future monitoring programs because of problems encountered with closed loop radio tracking collars.

Involvement of local media and conservation volunteers in the program engaged the local community and raised awareness of the conservation objectives of the Department for Environment and Heritage (DEH). It is recommended that the active involvement of the local community remains an important part the program and any future reintroductions.

2. Background

2.1 The species

Three subspecies of *Bettongia penicillata* have been recognised: *B. penicillata-ogilbyi* which inhabits the south west of Western Australia; *B. penicillata penicillata*, which occupied eastern and southern regions of Australia and is now considered extinct; and *B. penicillata tropica*, which is restricted to north east Queensland (QLD). However it is now widely accepted that the QLD population is a distinct species of Bettongia (*B. tropica)* and is being managed as such (Start *et al.* 1995). In the present report, the term 'Brush-tailed Bettong' or 'Bettong' refers to the Western Australian sub species *B. penicillata ogilbyi.*

Adult Brush-tailed Bettongs are typically 300-380 mm in length with a tail of 290-360 mm, and weigh from 1 – 1.5 kg. Males and females are similar in appearance and occupy individual home ranges, each including a nesting and feeding area. Nesting areas are territorial but feeding areas may overlap (Christensen, 1983). Breeding can be continuous, as females can give birth at 170 – 180 days and then every 100 days for the rest of their life of 4-6 years. Like many other macropods, the Brush-tailed Bettong exhibits embryonic diapause (Christensen,1983).

In WA, Brush-tailed Bettongs are found in open forests and woodlands. Populations established in SA have revealed an ability to utilise almost all available habitats from grasslands to woodland, with a preference for refuge sites offering shrub cover. It must be noted, however, that prior to the Lincoln NP reintroduction, all but one of these populations (Venus Bay CP) have been established and maintained in the absence of feral cats and foxes (Copley, van Weenan, 1999). The Brush-tailed Bettong is an opportunistic feeder and food consists largely of the fruiting bodies of underground fungi, supplemented by bulbs, tubers, seeds, insects, fruit, bark, resin and at times the foliage of shrubs. The proportion of fungal material in the diet is greatest in summer and autumn. Bettongs forage for food between dusk and a few hours before dawn (Christensen, 1983, Nelson, et al.1992). Brush-tail Bettongs spend the day in domed nests made of grass or shredded bark in a depression scraped in the ground under bushes, tussock grass or thick leaf litter. The tail is prehensile and can be used to transport nesting material. The Brush-tailed Bettong is fairly slow moving except when disturbed (Christensen, 1983).

2.2 Former distribution

Evidence from Aboriginal people and early explorers suggests that *B. penicillata* was once widespread and abundant over most of mainland Australia south of the tropics, including the central desert in WA and the southern region of the Northern Territory (Burbidge *et al*, 1988, Delroy *et. al*, 1986). Despite unconfirmed sightings on the Eyre Peninsula (Saunders & St John, 1987), *B. penicillata* appears to have disappeared from most of its southern range by the early 1900's and Central Australia by 1960. By 1975 there were only three known natural populations remaining in SW Western Australian (Burbidge, *et al*, 1988, Delroy *et al*, 1986). This decline resulted in the species being rated as endangered at the national level (CALM, 2004).

2.3 Conservation

2.3.1 Captive breeding and island reintroductions

A captive breeding program for *B. penicillata ogilbyi* was initiated by the South Australian National Parks and Wildlife Service in 1975, using animals from the Perth Zoo. The program produced a large number of animals, many of which were released to six South Australian islands (Delroy et al., 1986). The first such release took place on Bird Club Island near Port Augusta in 1979 (Nelson et al. 1992), with the most recent offshore island release undertaken on St Peter Island in 1994. These introductions have had mixed success, and regular monitoring and management is required to ensure their security from predators that may be introduced, and to provide genetic variability (Nelson, et al, 1992, van Weenan, pers. comm., 2004, Copley P., & van Weenan J., 1999).

2.3.2 Recovery Plans

A national Recovery Plan for the Brush-tailed Bettong was jointly prepared by the Western Australian Department of Conservation and Land Management (CALM) and the South Australian National Parks and Wildlife Service (SANPWS), and in 1991 was adopted under the Commonwealth Endangered Species program (Hall et al., 1991, Start et al., 1995). The Recovery Plan defined actions to be implemented over a period of up to ten years. These actions included the establishment of six or more wild populations on mainland WA, a wild population on mainland SA, the continued well being of Brush-tail Bettongs on the two larger South-Australian islands (St Peter and Wedge), and the establishment of monitoring programs in both states (Start et al, 1995).

Regular fox baiting with 1080 (sodium monofluoroacetate) poison in WA reserves containing bettong populations began in 1989 and was later expanded into other areas, leading to the expansion of many small Brush-tailed Bettong populations in WA (Start *et al.*, 1995, Start *et al.*, 1996). The first South Australian mainland reintroduction was successfully undertaken at Yookamurra Sanctuary in 1991 into an area protected by predator-proof fencing. Nelson *et al.* (1992) detailed the monitoring and future management requirements for currently existing re-introduced Brush-tailed Bettong populations in SA, and proposed the feasibility of establishing a second mainland population. Following great success in the recovery of Brush-tailed Bettongs in WA and SA, the National Recovery plan was reviewed in 1994 after only three years. The action plan was cut from 10 to 5 years, with the status of the species to be reviewed at the end of 1995 (Start et al, 1995).

A second mainland reintroduction was made to South Australia in Venus Bay Conservation Park in 1994 (Start, et al. 1995) (Figure 1). Venus Bay Conservation Park was unfenced when the initial reintroduction took place, but predator-proof fencing was subsequently erected to facilitate the reintroduction of other locally extinct species (D. Armstrong *pers. com.*, 2004). The reintroduction of 67 Brush-tailed Bettongs into Venus Bay CP has produced a healthy population of approximately 300 bettongs in 2004 (D. Armstrong *pers. com.* 2004) and animals from this population have been used for other reintroduction programs.

In November 1995, the recovery team recommended that the species be down listed, from Endangered to Conservation Dependant (Maxwell,1996). In 1996 the Brush-tailed Bettong became the first mammal in Australia to be deleted from list of threatened species as a result of conservation action (CALM, 2004, Start et al, 1998).

Following the de-listing of the species from State and Commonwealth Threatened Species Schedules, the focus of Brush-tailed Bettong recovery in South Australia is the trial reintroduction of the species to areas of its former range that are not geographical isolates, and where these reintroductions are part of larger scale ecological restoration programs (DEH, 2004).

3. The Lincoln National Park translocation proposal

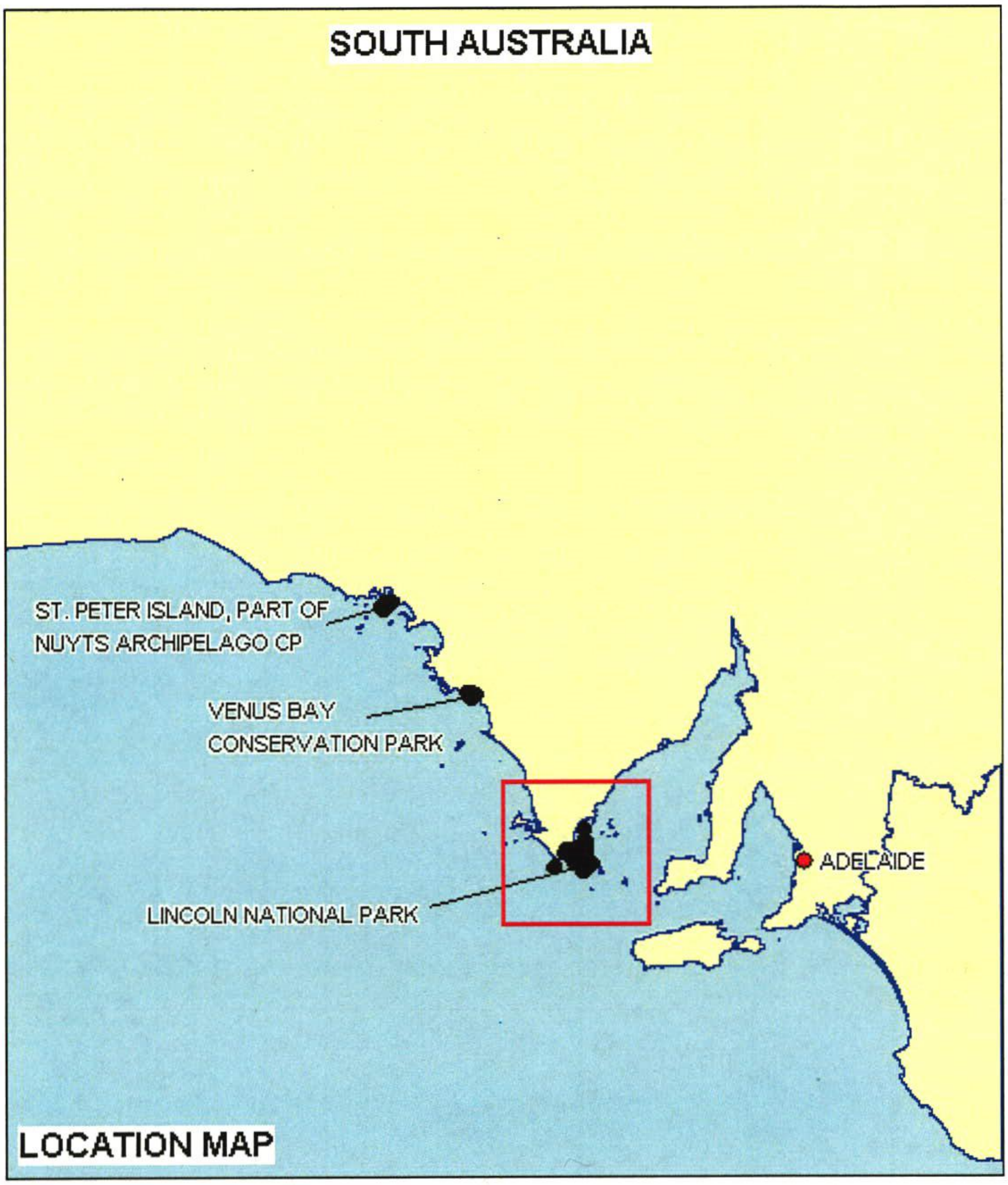
A proposal for the translocation of Brush-tailed Bettongs from Venus Bay Conservation Park to Lincoln National Park (LNP)(Fig. 1) was prepared in early 1999 (Copley and van Weenan 1999), and a subsequent proposal for an additional release was prepared in November 2000 (Cotsell 2000).

According to these proposals the general aims of the LNP Bettong reintroductions were to:

1. Re-introduce a locally extinct species into a former area of its range based on a habitat restoration approach rather than species recovery approach, as part of a larger district ecological restoration program operating on the Lower Eyre Peninsula (Williams & van Weenan, pers. comm., 2004).
2. Maintain a viable bettong population without the need for predator control fencing and within the resources of local DEH district staff.
3. Raise community awareness of ecosystem recovery works on the Eyre Peninsula.

The recovery of other locally extinct species such as the Brush-tailed Possum was considered less favourable in the region due to the negativity associated with this species (often considered a pest) (van Weenan, 2004, *pers. com.*) The 1999 proposal was approved by the South Australian Ethics Committee as Project No.15/99.

Figure 1. Location of the release site (Lincoln NP) and source populations (St Peter Island and Venus Bay Conservation Park).



4. Methods

4.1 The release site

Lincoln National Park covers an area of 29, 214 hectares of Jussieu Peninsula, and is characterised by five main vegetation types: 1) coastal dune association, 2) drooping sheoak (*Allocasuarina verticillata*) and dryland tea-tree (*Melaleuca lanceolata*) association, 3) mallee woodland complex, 4) tussock grassland incorporating *Gahnia sp.*, and 5) coastal cliff heath association. The only species of macropod currently recorded from LNP is the Western Grey Kangaroo *(Macropus fuliginosus).*

The release site was situated on Donington Peninsula, LNP, approximately 3.5 km south of the Cape Donington lighthouse. Donington Peninsula presented an ideal location for the reintroduction because of easy access throughout the release area and limited dispersal opportunities for bettongs created by the peninsula. The narrow neck of the Jussieu Peninsula where it is connected to Eyre Peninsula was also expected to assist in controlling predator migration into the park (Copley & van Weenan, 1999).

Plate 1. LNP Bettong release site 1, displaying typical habitat of release sites

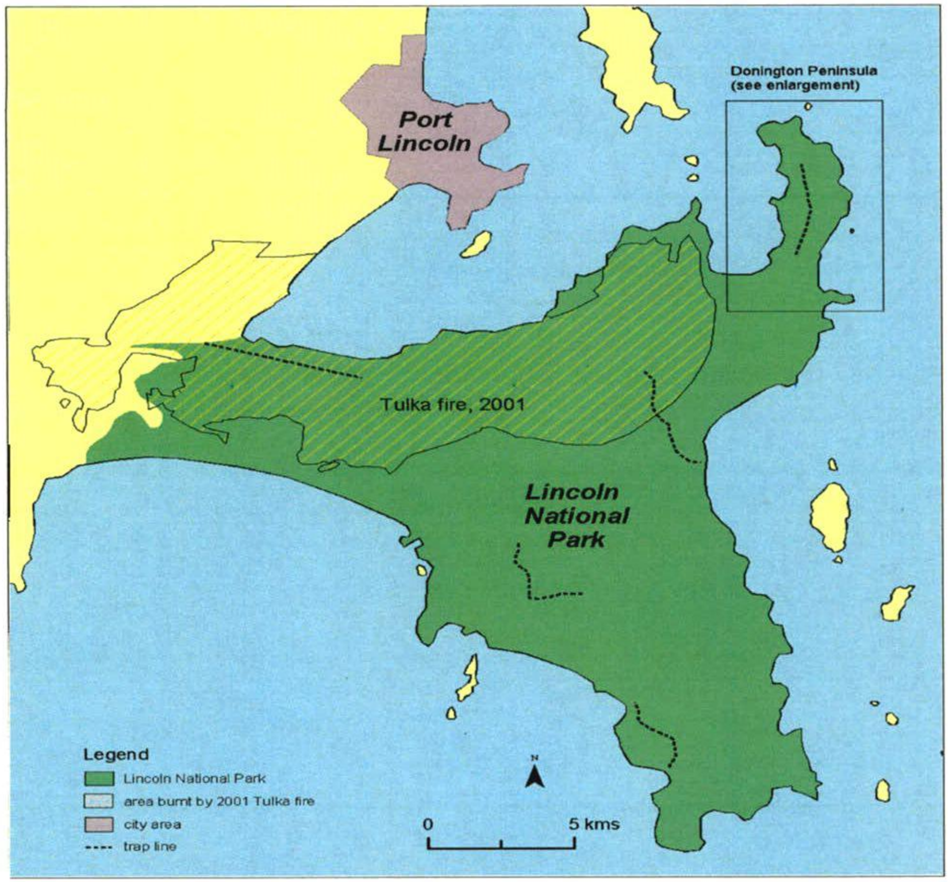


Figure 2a. Map of Lincoln National Park, showing the extent of the 2001 Tulka fire (hatched) and trapping transect locations (broken lines).

Produced by: Steve Ball for Department for Environment and Heritage (DEH), South Aust.
Data sources: All data supplied by Regional Conservation, DEH, and adapted by S.Ball.
Grid: GDA94, MGA Zone 53
Data analysis: ArcGIS 8 (geog. information system)
Compiled: Sept. 2004, S.Ball - contract GIS support

Figure 2b. Satellite image of Donington Peninsula (RGB image taken in 2000 using Landsat ETM+).

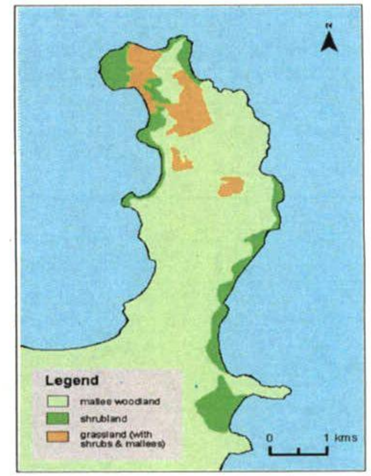


Figure 2c. Habitat map of Donington Peninsula. Mallee woodland comprises mixed mallee woodland with Melaleuca understorey. Shrubland includes tall Melaleuca shrubland, low closed Alyxia shrubland, and Westringia shrubland with isolated stands of mallee eucalypts and Allocasuarina. Grassland includes regenerating cleared areas with Myoporum shrubs, and open grassland with isolated stands of mallee eucalypts.

4.2 Release site preparation

Fox and rabbit control was undertaken to prepare the release site, as feral animals could easily prevent the successful establishment of a Brush-tailed Bettong population (Stewart, 1999)(See 4.6 Threat Abatement). Rabbits have been identified as a contributing factor to the decline of Brush-tailed Bettongs over much of their previous range (Delroy et al. 1986). Rabbits not only compete with bettongs for food resources, but can also directly effect the population density of introduced predators, providing a prey base to keep fox and cat numbers at high levels (Start et al. 1995).
During the immediate months leading up to the releases, extra 1080 baiting, spotlight shooting of rabbits and foxes, and rabbit warren blasting was undertaken to prepare the release area. Rabbit control was undertaken in areas of warren activity on the upper Donington Peninsula prior to release 1 and 2 and immediately after release five. Intensive site preparation was undertaken for the first three bettong releases to LNP and to a lesser degree the fourth and fifth release. Predator and rabbit control was less intensive for releases 4 and 5 because local staff were occupied with fire fighting and park restoration duties associated with the large bushfire of February 2001.

4.3 Source of animals for release

Bettongs were initially sourced from Venus Bay Conservation Park (VBCP) because of the genetic diversity within this population. The VBCP population was established in 1994 and originated from the translocation of wild bettongs (*B. penicillata ogilbyi*) from the Dryandra Native Forest Reserve, Western Australia in 1994 (Armstrong, pers, comm, 2004). VBCP is 4780 hectares in area, and experiences a semi-arid climate of hot dry summers and cool wet winters, with a mean rainfall of 370 mm. Dominant tree species are Yorrell (*Eucalyptus gracilus*) and red mallee (*E. oleosa*). Shrubs include Angle Wattle (*Acacia anceps*), Inland tea tree (*Melaleuca lanceolata*), Sheepbush (*Giejera linearfolia*) and Bluebush (*Maireana spp.*) with Spinifex (*Triodia*) a dominant ground cover (Priddel & Wheeler, 2003).

To strengthen the established population and provide new genetic material 30 additional animals from St Peter Island were released into LNP, 18 months after the initial release. *B. penicillata ogilbyi* were introduced to St Peter Island (SPI) in 1989. The population originated from a number of captive colonies with the majority coming from SA Department for Environment and Heritage breeding stock housed at Monarto Zoo, and from the CSIRO Division of Wildlife and Ecology in Canberra (Start *et al.*, 1995). St Peter Island is 3,439 ha in area and experiences a semi-arid climate with a mean annual rainfall of 300 mm. Much of the island is covered with introduced grasses, however five other native vegetation types can be identified. These include a shrubland of Native Juniper (*Myoporum insulare*) and Coastal Daisy-bush (*Olearia axillaris*), and remnant mallee trees (*Eucalyptus anceps*) (Nelson et al. 1992).

4.4 Translocation procedure.

Bettongs were released into LNP on five occasions with the first release undertaken in September 1999. The translocation method used was developed as a result of several previous bettong translocations carried out by DEH in South Australia (Stewart, 1999).

4.4.1 Trapping for translocation

Trapping was conducted in VBCP on 5/9/99, 14/9/99, 21/11/99 and 30/3/01, and on SPI on 3/4/01 using treadle-operated cage traps (23 x 23 x 60 cm, *Sheffield Wire Products*, Western Australia) baited with a mixture of peanut butter and rolled oats. Traps were set along major tracks in areas where relatively high densities of bettongs were known to exist. Once set, traps were left until two hours after dark, and then checked repeatedly until sufficient animals had been captured. Trap location, ear tag number, sex, weight and size of head, hind foot and details of any pouch young size were recorded for all bettongs captured, and new captures were tagged.

4.4.2 Selection criteria for translocation

For a bettong to be selected for translocation to LNP, it had to weigh over one kilogram, be preferably younger than five years old and in most instances, if a female with pouch young, pouch young had to be less than 40mm in size (Stewart, 1999).

4.4.3 Transportation to release site and collar fitting

Each captured bettong was placed in an individual, labelled hessian sack, with a large ball of peanut butter and rolled oats, and then placed inside an individual cage trap. External labelling of the sacks enabled the chance to swap bettongs if more suitable bettongs were captured later in the night (Mack, 1999). Selected bettongs were then transported to a shed for storage overnight, before translocation to Port Lincoln (2.5 hours travel from Venus Bay to Port Lincoln). In the case of St Peters Island, bettongs they were transported via boat to Ceduna and then driven to Lincoln (total 5 hours travel).

Three different types of radio collars were used during the radio-tracking program (see section 4.4.1). All collars incorporated a closed loop design and were attached via a small nut and bolt and tightened with a drop of glue (*Loc-tite thread locker 243*). Radio collars were fitted to a percentage of the captured bettongs at the Port Lincoln National Parks and Wildlife workshop depot in the afternoon before the release. This allowed for bettongs to become accustomed to the collars before release. The collars were pre-tested before fitting to ensure that they were working, and that the most appropriate signal frequency had been selected. The collared bettongs were returned to their hessian sacks, placed inside a cage trap and left in the workshop office before being transported to LNP later in the evening. The maximum time elapsed between capture and release was 22 hours (Stewart, 1999).

4.4.4 Release strategy

A total of 113 bettongs were released into LNP over 5 translocation events between September 1999 and April 2001 (Table 1). The first two translocations were undertaken in September 1999. As male bettongs have been known to disperse widely once released, two separate release events were chosen, rather than one large, in order to minimise the distances moved by male bettongs in the initial days after release. A group of 13 females was released first so that these animals would mark and scent the release area before the males were released. The initial animals were given a week and a half to settle before the second release was undertaken, which included 3 males and 2 females. The second release occurred further north on the Donington Peninsula. Theoretically the released males would travel south through vegetation that had already been scented by the females, therefore helping to contain their movements to Donington Peninsula (Stewart, 1999). The third release (15/9/99), marked the official translocation of bettongs to LNP, and was conducted with volunteers and the SA Minister for the Environment (Stewart, 1999). The fourth release (30/3/01) was also a public event, with 150 volunteers convening at Donington cottage in LNP to celebrate their achievements and efforts in conservation works, as part of the International Year of the Volunteer. Volunteers witnessed the release of 30 Brush-tailed Bettongs. Twenty one volunteer groups were represented at the gathering. Many volunteers had the opportunity to see Brush-tailed Bettongs for the first time (Freak, 2001).

During each translocation event bettongs were released as a group on dusk between 1800 – 1830 hours. On release, the hessian sacks were untied and placed on the ground. The bettongs were then able to leave the bags when they were ready (Stewart, 1999). The release areas were checked the next morning to ensure that all of the bettongs had left the hessian sacks. The sacks were left at the release sites for up to seven days post the release. This ensured that bettongs were able to recognise their own scent in the release areas (Stewart, 1999).

Plate 2. LNP bettong release 4 was a public event to celebrate the International Year of the Volunteer in March 2001.

Table 1. Summary of Brush-tailed Bettong release events in LNP. VBCP = Venus Bay Conservation Park, SPI = Saint Peter Island Conservation Park

Date	Source	Total number released		Individuals radio collared on release		Release site Coordinates (WGS 84)
		Male	Female	Male	Female	
6/9/99	VBCP		13		13	53, 591416, 6154138
15/9/99	VBCP	3	2	3	2	53, 591615, 6155116
21/11/99	VBCP	11	15	4		53, 591615, 6155116
30/3/01	VBCP	15	25	2	4	53, 591419, 6154157
4/4/01	SPI	12	27	1	5	53, 591419, 6154157
	Total	41	82	9	24	

4.5 Monitoring

A contract ecologist was employed for the initial six weeks of the program to intensively monitor the bettongs, manage a database of tracking records, and train local staff in radio telemetry. After this initial period a contract project officer was employed for a further 8 weeks. Local DEH staff played a central role in managing the project and on occasions received volunteer assistance. Additional funding for bettong monitoring and predator control was sought from DEH and was granted on a casual basis from March 2001 to August 2003. (Appendix 4. Summary of staff, contractor and volunteer involvement).

4.5.1 Radio telemetry monitoring

A total of 54 animals were radio collared over the 4 years from September 1999 to November 2003. Usually there would be at least 10 animals monitored at one time. Radio tracking allowed monitoring of bettong nest site locations, movement, and survival. Initially, daily locations were found with a hand-held three element *Yargi* antennae attached to a *Icom Rx5* telecommunication receiver (*Biotelemetry Tracking*, Adelaide) and were recorded in AMG WGS 84 datum using a handheld GPS unit (*GARMIN 12*). When a bettong was located by radio tracking, a description of habitat, nest if observed, and note of same or new location compared to previous tracked site was recorded. Care was taken not to disturb bettongs whilst radio tracking and it was possible to get a good fix on the bettong nest location without venturing too close to the nest and disturbing its occupant. All data was transferred to a *Microsoft Excel* datasheet in the Port Lincoln DEH office. The locations of all tracked Bettongs were also drawn onto A3 size maps of the Donington Peninsula. Intensive monitoring of newly released bettongs decreased over a three month period, from daily tracking, to once a week, fortnightly then at least once a month.

Vegetation cover and topography greatly affected radio collar signal strength. In ideal conditions signals from collars could be detected up to 2 km away, but were limited to 100 m in some situations. Substantial effort was therefore required from staff and volunteers to intensively monitor bettongs during the first few weeks of each release. The radio tracking collars originally used in the program were *TX 1 LDL-M* low drain loop transmitters with mortality switches and three-month battery life (*Biotelemetry Tracking*, Adelaide). Possible radio collar failure was first noted in the *Biotelemetry Tracking* collars in October 1999, when three male bettongs were unable to be located after extensive searching. Collars were replaced with a lighter *TX 1 LDL* 6-month battery life, non-mortality loop transmitter collar (*Biotelemetry Tracking*, Adelaide)(Freak, 2000a) in October 2000. In August 2002, newly-fitted collars failed just days after fitting, or gave inconsistent signal strength. This was believed to be caused by faulty batteries used during re-battery, and collar failure proved to be an ongoing problem. Replacement collars were provided by the supplier and similar problems were encountered between August 2002 and June 2003, with many days of extra trapping required for collar replacement. In June 2003 collars of a similar tune loop aerial model with 6-month battery life (*Microlite LTM*) were purchased from *Titley Electronics* (Ballina, NSW). Although the new collars worked, they had a smaller transmission range than the collars used previously, which made radio tracking more time consuming. Over four years of radiotracking, nine collars had to be removed from animals due to neck injury (in three instances collars could be replaced after neck injuries had healed), five collars had to be adjusted / loosened, four faulty collars were removed and two collars repeatedly transmitted very weak signals.

A fixed wing *Cessna* aircraft with a 3 element *Yargi* antennae fixed to each wing and connected to a *Icom Rx5* receiver, was used to locate missing animals on three occasions. In April 2002 two of the four missing bettongs were located by aerial radio tracking within 30 minutes. A second aerial radiotracking survey was made in November 2003 in order to locate bettongs, which could not be tracked after three months of extensive radio tracking from the ground (August – September 2003). As this search was unsuccessful, a decision was made to remove all collars from radio tracked animals and concentrate on monitoring the bettongs via trapping alone, and to concentrate effort on analysing the data collected from four years of radiotracking and trapping.

4.5.2 Trapping

Treadle-operated cage traps (23 x 23 x 60 cm, *Sheffield Wire Products*, Western Australia) were used during trapping exercises. Traps were placed in hessian bags to provide trapped animals with protection and baited with a quarter of a peanut butter sandwich.

<u>Transect trapping</u>
A network of 5 permanent trapping transects was established in LNP in April 2000 to gain data on bettong presence / absence throughout the park. These transects consisted of 40 trap locations marked and numbered with iron droppers, spaced 100 metres apart along roads. Transect locations were chosen by considering where the animals were released and how their distribution could be best monitored over time (Fig. 2). Transects were trapped at least once a year, with the trapping transect positioned near the release area (Donington Peninsula) trapped more frequently.

<u>Targeted trapping</u>
Trapping was also undertaken by placing 2 or 3 cage traps in close proximity to where an animal was tracked during the day. This trapping was undertaken to check bettong health and most often to replace collars.

<u>Processing of animals</u>
Traps were checked early in the morning and captured animals weighed, assessed for reproductive status, checked for neck damage from the radio-collar and any parasites. Animals were then assigned a condition classification of poor, good or excellent (based on feeling any boniness and comparing previous weights). Radio collars were removed from

any animals showing neck damage from collar rubbing. Collars were replaced at a later date if wounds had fully healed.

The presence of pouch young was determined by an experienced handler feeling the outside of the pouch. The snout-vent length of pouch young was estimated by feel. Inspection of the inside of pouches was not often undertaken, due to the stress caused to the adult and the risk of pouch young being thrown.

If small pouch young were ejected from the pouch during the trapping process, they were returned to the pouch and the pouch closed with adhesive tape. The female was then later able to remove the tape when settled. Larger pouch young (at emergent stage) were placed back into the cage with the female. The cage was then covered in dense leafy branches to darken the inside of the cage, the cage wired open and clumps of dense leafy branches placed in the trap entrance. The cage was then left overnight and retrieved the next day, once the animals had exited.

Bettong scats left in the cage or catch bag were collected during trapping in July 2004. These scats were provided to mycologist Dr Teresa Lebel for analysis. The few scat samples collected during trap exercises before June 2004 were not studied.

4.5.3 Spotlighting

In February 2002 a bait-layer towed behind a quad bike was used to spread a 11 km-long line of oats through the area of Donington Peninsula inhabited by bettongs. On the following two evenings local DEH staff conducted a spotlight survey along the length of the trail. DEH staff also recorded the presence of bettongs during spotlight surveys for predators on 29/9/99, from 2/7/99 to 7/12/99, 2/6/00, 25/9/00, 1/11/00, 4/5/01, from 26/4/01 to 30/4/01, 29/6/01, from 2/7/01 to 7/7/01, from 4 /9/01 to 7/9/01, 1/5/02, 28/8/02 and 29/5/03.

4.5.4 Anecdotal observations

Observations of bettong presence (sightings, tracks and diggings) were made during daytime monitoring and routine park duties, as well as night park patrols, Bush-Stone Curlew surveys and biannual small animal surveys.

4.5.5 Determination of the causes of death

The remains of all dead bettongs were retrieved and examined where possible to determine possible cause of death. Teeth marks were observed on the plastic coating of some of the brass loop collars of bettongs that were found dead. Eighteen radio-tracking collars (5 in April 2001, 8 in May 2001 and 5 in September 2003) were sent to the Forensic Odontology unit of the University of Adelaide for analysis of teeth indentations in order to identify the animals responsible. A comparison of marks on the collar was made with likely predators of the region, *Felis catus* (cat), *Vulpes vulpes* (fox) and *Canis familiaris* (dog/dingo).

4.6 Threat abatement

4.6.1 Foxes

The benefit of 1080 fox baiting for the protection of Brush-tailed Bettongs has been illustrated at several sites in south west Western Australia (Western Shield program), with substantial population increases of Brush-tailed Bettongs (up to 400%), as well as increases in distribution range (CALM, 2004). Studies by King *et al.* (1981) have indicated that Brush-tailed Bettongs have an extremely high tolerance to 1080 poison. The LNP program of quarterly saturation baiting with 1080 dried meat baits began in 1997 and has continued to the time of writing. The program involved laying baits every 300-400 metres along each road, walking track and accessible beach in the park. Baits used in the program consisted of dried kangaroo meat and fresh fish baits (tuna, tommies, pilchards) injected with 3 mg of 1080 (monosodium fluroacetate) poison. Opportunistic baiting was also carried out, which involved park staff target baiting "hot spots" where and when evidence of predator activity was found. Volunteers (particularly the Friends of Southern Eyre Peninsula Parks group) greatly assisted with fox baiting activities. Extra baiting was carried out by volunteers and staff whilst radio-tracking bettongs. Opportunistic baiting was also undertaken by DEH staff and 'Work for the Dole' crews when and where predators were detected during other park management duties.

Permanent bait stations, spotlighting fox counts and regular predator track monitoring programs were established to help assess the overall effectiveness of the 1080 baiting program (Williams, pers.comm, 2004). Bait stations were established primarily to monitor trends in predator activity. Both bait stations and spotlight surveys have proven to be useful techniques to monitor success of predator control programs (Williams, S., *pers. comm.*, 2004). Bush Stone-curlews were also surveyed quarterly by using recorded calls to elicit responses from nearby Stone-curlews. The ground-nesting Bush Stone-curlew is highly vulnerable to fox predation and an increase in their numbers and breeding success in LNP can indicate successful fox control (Gates, 1999).

4.6.2 Rabbits

Rabbit abundance declined in Lincoln National Park with the arrival of Rabbit Calicivirus Disease (RCD) in 1998 /1999. However, rabbit abundance slowly increased in subsequent years in the ideal habitat provided by open grasslands areas of Donington Peninsula. Rabbits were controlled on Donington Peninsula by blasting warrens and laying 1080 oat baits. Control of rabbits and the destruction of warrens was also thought to assist with the control of feral cats. Warrens were initially flagged in July / August 1999 then blasted December 1999, flagged in Feb 2000 and late April 2001 with additional flagging and blasting in July 2001 and September 2001. A trial 1080 poison oat trail was carried out in April 2002. In February 2002 Greencorps participants mapped rabbit warrens and recorded cat and fox activity by walking set transects in the Donington area, in preparation for future warren blasting.

4.6.3 Cats

Based on evidence that feral cats were predating the radio-collared bettongs (James et al., 2002), concentrated efforts were made to spotlight for and trap feral cats from winter 2001

to autumn 2002. Under the South Australian Animal and Plant control act, cats are not a proclaimed species and therefore cannot be legally controlled with poison bait.
Wire cage traps (50 x 50 x 80 cm) and soft jaw leg-hold traps (*Victor Soft Catch*) were set in areas of cat activity. Attractants including *Feline Attracting Phonic* (*FAP*) devices (available from Department of Conservation and Land Management WA), pot plant bird callers (*Dick Smith Electronics*), domestic cat faeces, food baits (rabbit, tuna, pilchards, kangaroo, liver) and tin foil were used in conjunction with the traps.
In July 2001 and May 2003 Sporting Shooter volunteers from the Conservation Branch of Sporting Shooters Association camped in the park and undertook spotlight transects, cage trapping, eco trapping and leg hold trapping in an attempt to catch feral cats sighted on the Donington Peninsula

Spotlight shoot surveys for cats and foxes were carried out approximately every 4 months with efforts concentrated in the bettong release area.

4.7 Financial and human resources

As highlighted by Fischer and Lindenmayer (2000), few animal relocation studies report the cost of the relocation attempt. The value of animal relocations as a conservation tool could be enhanced through better financial accountability and greater effort to publish the results of relocations, even ones that are unsuccessful.

The LNP Brush-tailed Bettong reintroduction program was initially funded by the DEH General Reserves Trust through the Ark on Eyre Program, and later by the DEH district operating budget for Habitat and Wildlife Management. The reintroduction program was planned in a way that DEH staff based in the region had responsibility for the management and monitoring of the population after the initial release period (Copley and van Weenan, 1999). Since the program began in 1999, funds have been sought and granted to employ a contractor (on several occasions) to monitor the bettong population and undertake predator control, through

- Wildlife Conservation Fund (a SA non-government organisation)
- Nature Foundation SA Inc.(a SA non-government organisation)
- Tulka Fire Asset Reinstatement funds (DEH)

Following the large bushfire of February 2001, increased predator numbers were observed in the bettong release area. DEH Tulka Fire Asset Reinstatement funds were sought and granted to employ a contractor to assist with predator and rabbit control and bettong monitoring.

To assist with fox baiting and small animal surveys in LNP, the following grants were also applied for and received through the Friends of Southern Eyre Peninsula parks:

- DEH Directors grant 2001
- Natural Heritage Trust Biodiversity Grant 2002
- Natural Heritage Trust Fox Baiting Grant 2002

Refer to Appendix 3 and 4 for details of financial and human resources.

4.8 Statistics

A statistical analysis of bettong survivorship in Lincoln National Park between 1999-2002 and a power analysis of the sampling design for radio-tracking were undertaken by Steve Ball in July 2004. See Appendix 2 for details of methods.

4.9 Community Involvement

Local conservation volunteers played a large role in the bettong reintroduction program. Assistance was provided by volunteers for: preparing grant applications, fox baiting, spotlight predator surveys and trapping, collection of baseline biological data for Lincoln National Park during animal surveys, bettong monitoring and promotion of the bettong program to the wider community (particularly in highlighting the plight of the Bettongs following the 2001 bushfire in Lincoln National Park).

5. Results

Initial results from the first three releases were reported by Stewart(1999) and Mack (2000) with further progress reports prepared by DEH district staff Freak(2000a, b, 2001), Freak *et al* (2001), Martin (2002) and Cotsell (2002).

5.1 Release site preparation

There was little and infrequent fox or cat activity observed at the time of releases 1, 2 or 3 into Lincoln National Park in Spring 1999 (Young, *pers. comm.* 2004). Some evidence of low predator activity within the release area was observed during releases 4 and 5 in Autumn 2001 after the Lincoln National Park fire.

5.2 Translocation procedure

Brush-tailed Bettongs were readily trapped from the source populations. The majority of the Brush-tailed Bettongs in the LNP translocations did not appear to be significantly stressed by the relocation. The translocation methods used can be seen as successful, with only one of the 113 adult bettongs, and 2 of the known pouch young not surviving the relocation. The individual adult that died during release was a female believed to be stung numerous times by inch ants, whilst being trapped for translocation at Venus Bay Conservation Park in March 2001 (Freak, 2001). The two pouch young died during the November 1999 translocation. One was a large pouch young ejected from the pouch when a female was trapped in VBCP. An attempt was made to translocate the female after a visit to the local vet. The vet applied a stitch with the aim of keeping the joey in the pouch, but upon release the young was again ejected and was subsequently euthanased. During the release into LNP another joey was ejected and also euthanased as it was too young to hand rear (Mack, 2000).

5.3 Radio telemetry

Movement of released bettongs

Bettongs dispersed in all directions from the release sites (Figs 3 & 4) and were considered settled when they were found in the same location after 4 consecutive radio monitoring events. The time taken for bettongs to settle into a home range from date of release varied, but in general took from one week to a month (Table 2). Animals in subsequent releases settled quicker (1 to 2.5 weeks) than those in the initial release (on average one month)(Table 2). SPI bettongs in the 5th release were an exception, taking on average 3 weeks to settle (Table 2). Only one of the collared bettongs bred in LNP was recorded as settled, taking over 5 months. Similarly, only one of the 16 bettongs collared after 1/10/2001 were observed to have settled, and took over a month to do so.

Females tended to move further from the release site and range more widely than males (Table 3). The largest distance travelled by a radio tracked individual was 6.2 km south of the initial release area, by female bettong number 8 (tagged 2111). This bettong travelled south soon after its release. The collar was removed from Bettong 8 at this location, due to monitoring difficulties. The second furthest distance travelled was 3.7 km by female 46 (tagged 2129), followed closely by male 30 (tagged 1947) at a distance of 3.6 km from initial release area. In addition to taking longer to settle, animals from releases 1 and 2 also moved further from the release site (Table 4, Figs 4a and b).

Disturbances

Events that caused bettongs to become unsettled and move substantial distances from their usual nest sites included release events, a large bushfire, predator pressure and stormy weather conditions (Freak 2000 a). During rough weather conditions and thunderstorms most bettongs with nest sites near the exposed coast were observed to move inland (Mack, 2000). Obvious and pronounced increases in movement were recorded for seven radio tracked bettongs in the days leading up to their deaths by predation. Disturbance from targeted trapping activity or by nest flushing during radio tracking also caused bettongs to move. In these instances bettongs often returned nest sites they had previously used.

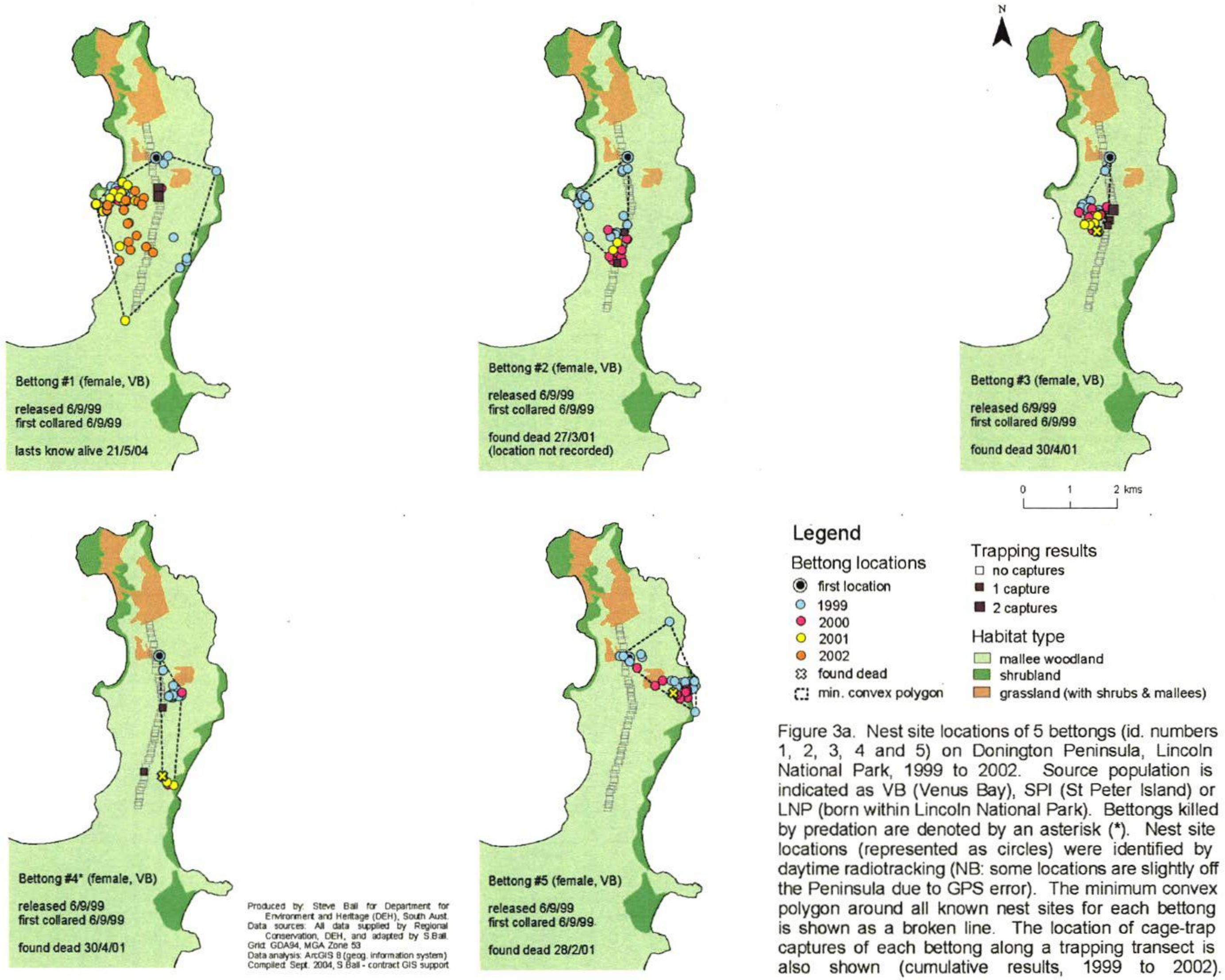
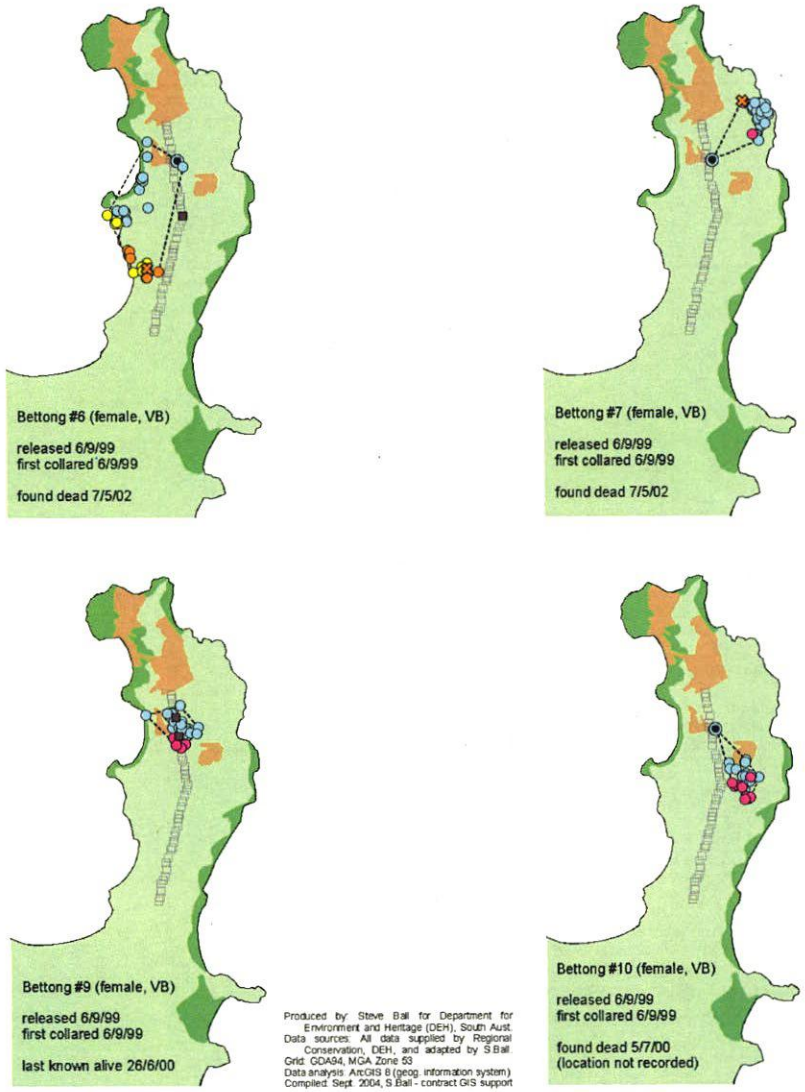


Figure 3a. Nest site locations of 5 bettongs (id. numbers 1, 2, 3, 4 and 5) on Donington Peninsula, Lincoln National Park, 1999 to 2002. Source population is indicated as VB (Venus Bay), SPI (St Peter Island) or LNP (born within Lincoln National Park). Bettongs killed by predation are denoted by an asterisk (*). Nest site locations (represented as circles) were identified by daytime radiotracking (NB: some locations are slightly off the Peninsula due to GPS error). The minimum convex polygon around all known nest sites for each bettong is shown as a broken line. The location of cage-trap captures of each bettong along a trapping transect is also shown (cumulative results, 1999 to 2002).



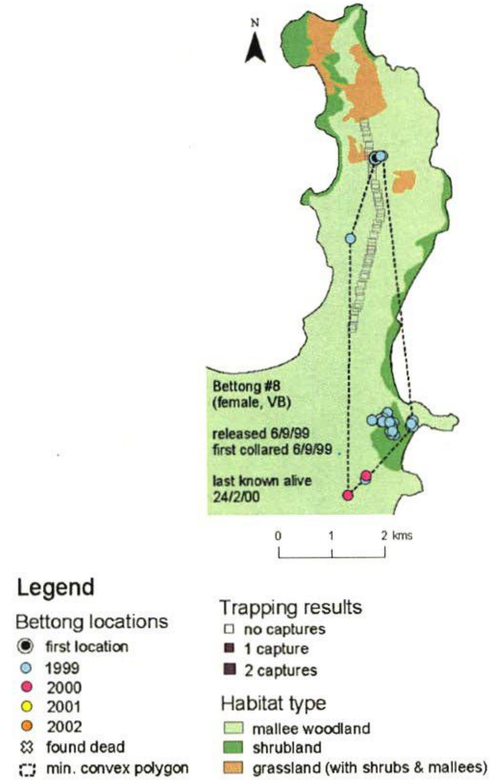
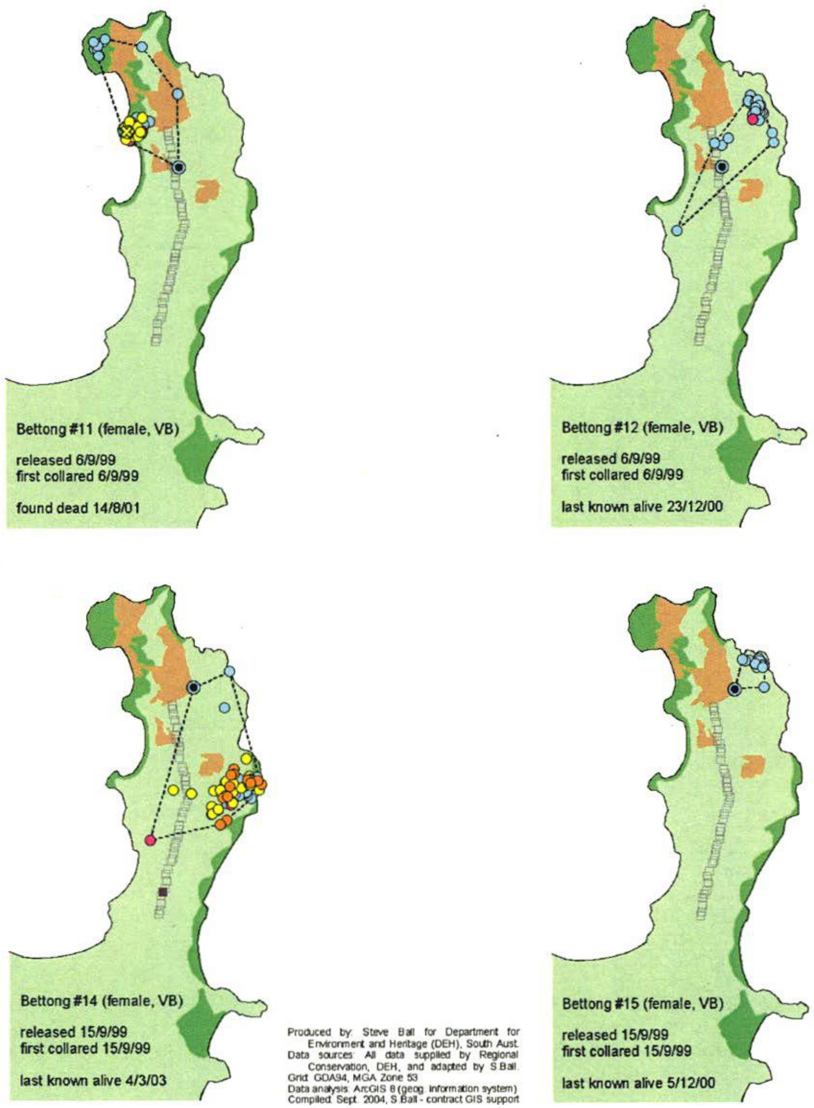


Figure 3b. Nest site locations of 5 bettongs (id. numbers 6, 7, 8, 9 and 10) on Donington Peninsula, Lincoln National Park, 1999 to 2002. Source population is indicated as VB (Venus Bay), SPI (St Peter Island) or LNP (born within Lincoln National Park). Nest site locations (represented as circles) were identified by daytime radiotracking (NB: some locations are slightly off the Peninsula due to GPS error). The minimum convex polygon around all known nest sites for each bettong is shown as a broken line. The location of cage-trap captures of each bettong along a trapping transect is also shown (cumulative results, 1999 to 2002).



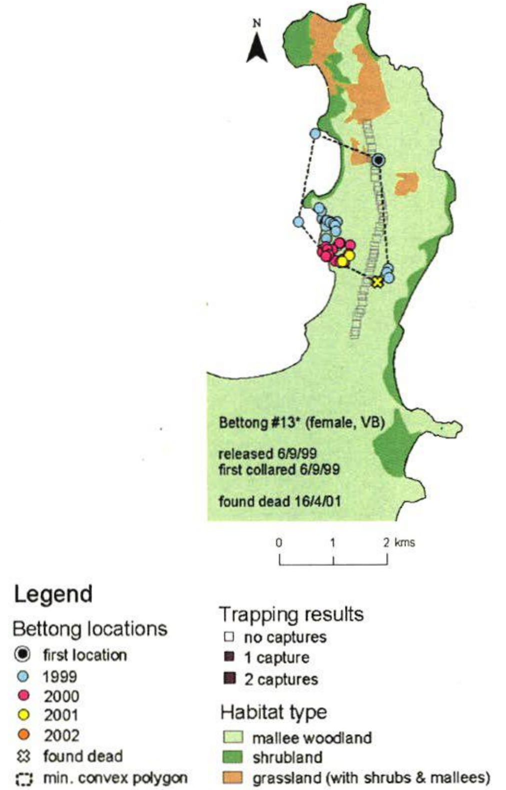
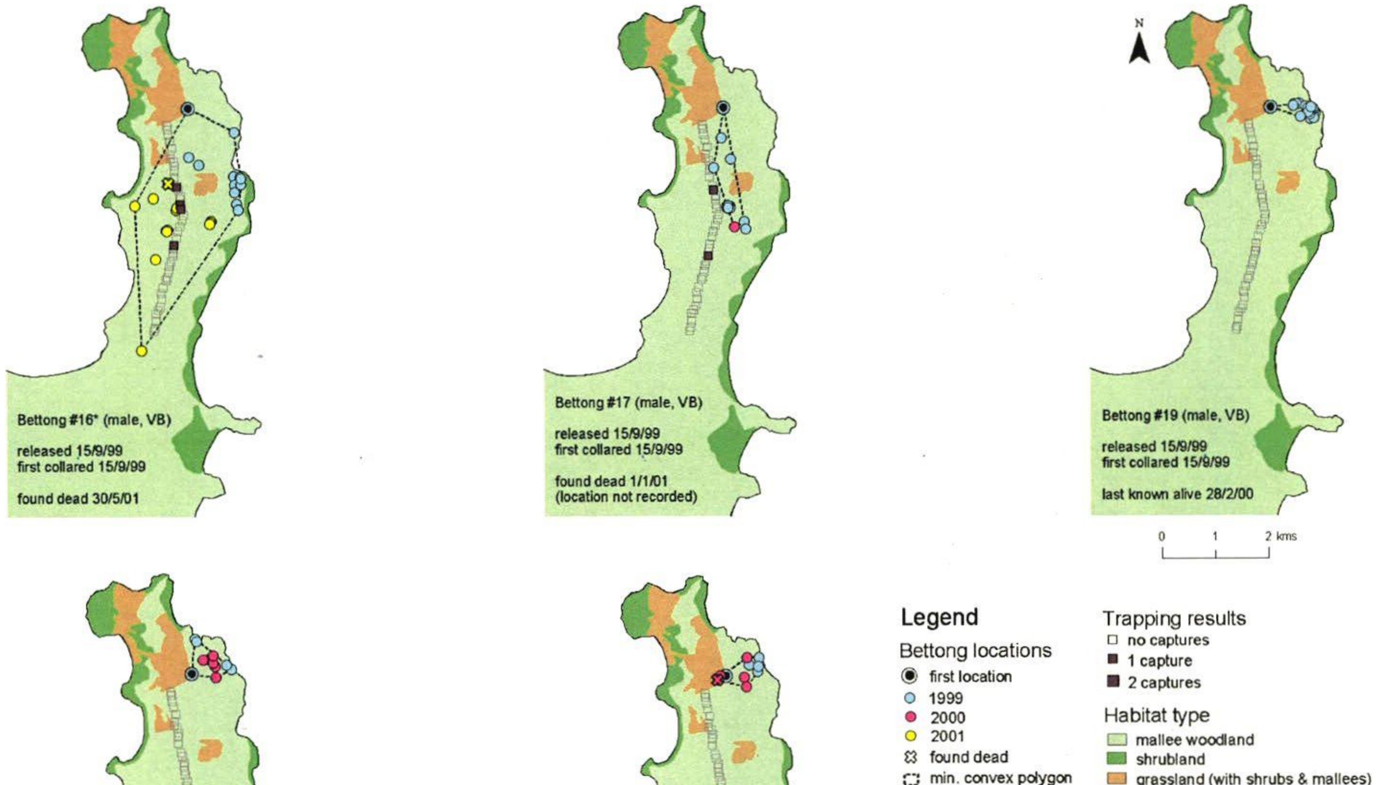


Figure 3c. Nest site locations of 5 bettongs (id. numbers 11, 12, 13, 14 and 15) on Donington Peninsula, Lincoln National Park, 1999 to 2002. Source population is indicated as VB (Venus Bay), SPI (St Peter Island) or LNP (born within Lincoln National Park). Bettongs killed by predation are denoted by an asterisk (*). Nest site locations (represented as circles) were identified by daytime radiotracking (NB: some locations are slightly off the Peninsula due to GPS error). The minimum convex polygon around all known nest sites for each bettong is shown as a broken line. The location of cage-trap captures of each bettong along a trapping transect is also shown (cumulative results, 1999 to 2002).



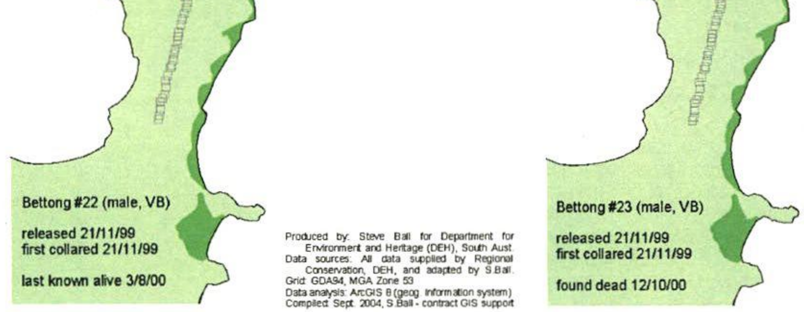


Figure 3d. Nest site locations of 5 bettongs (id. numbers 16, 17, 19, 22 and 23) on Donington Peninsula, Lincoln National Park, 1999 to 2001. Source population is indicated as VB (Venus Bay), SPI (St Peter Island) or LNP (born within Lincoln National Park). Bettongs killed by predation are denoted by an asterisk (*). Nest site locations (represented as circles) were identified by daytime radiotracking. The minimum convex polygon around all known nest sites for each bettong is shown as a broken line. The location of cage-trap captures of each bettong along a trapping transect is also shown (cumulative results, 1999 to 2001).

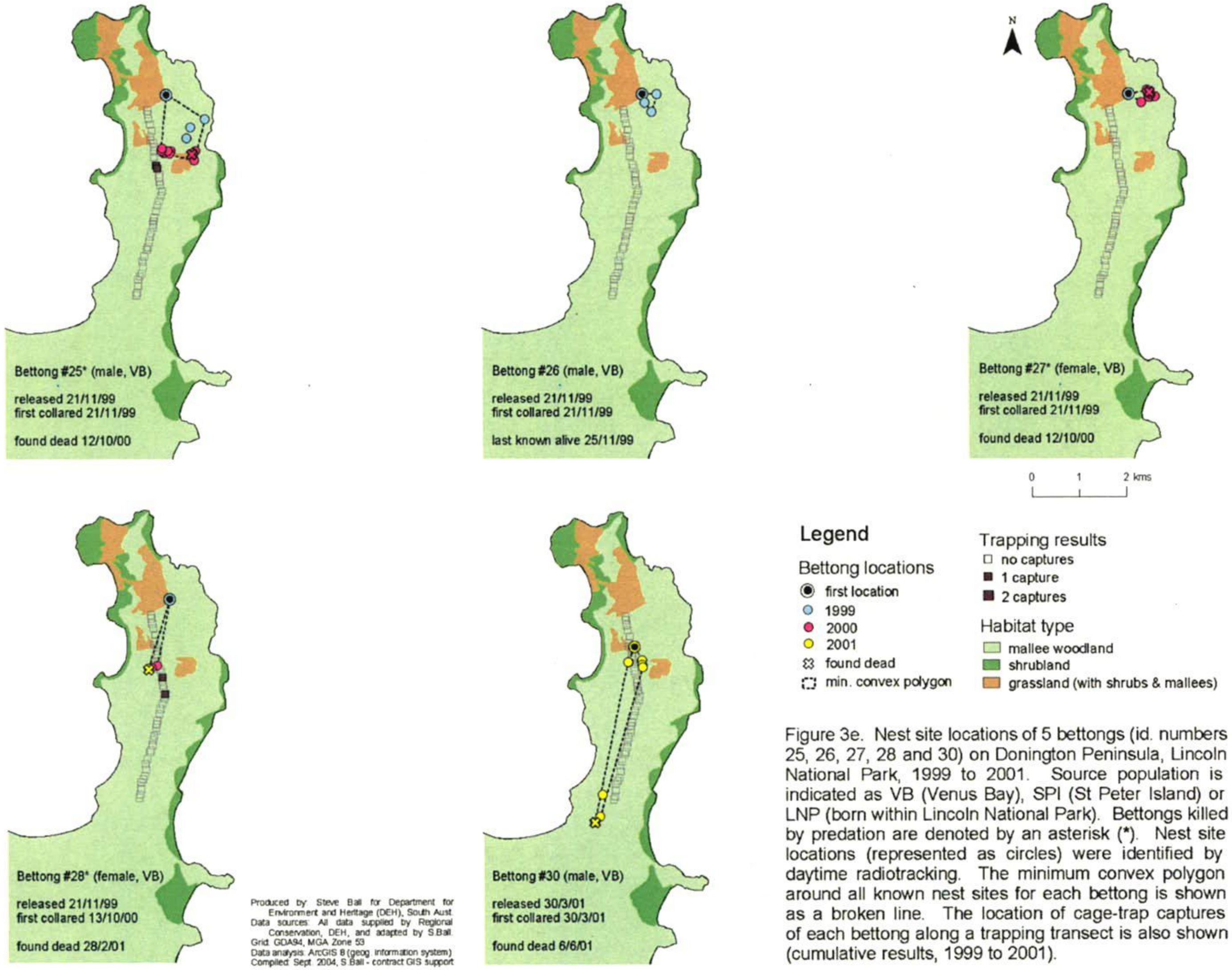


Figure 3e. Nest site locations of 5 bettongs (id. numbers 25, 26, 27, 28 and 30) on Donington Peninsula, Lincoln National Park, 1999 to 2001. Source population is indicated as VB (Venus Bay), SPI (St Peter Island) or LNP (born within Lincoln National Park). Bettongs killed by predation are denoted by an asterisk (*). Nest site locations (represented as circles) were identified by daytime radiotracking. The minimum convex polygon around all known nest sites for each bettong is shown as a broken line. The location of cage-trap captures of each bettong along a trapping transect is also shown (cumulative results, 1999 to 2001).

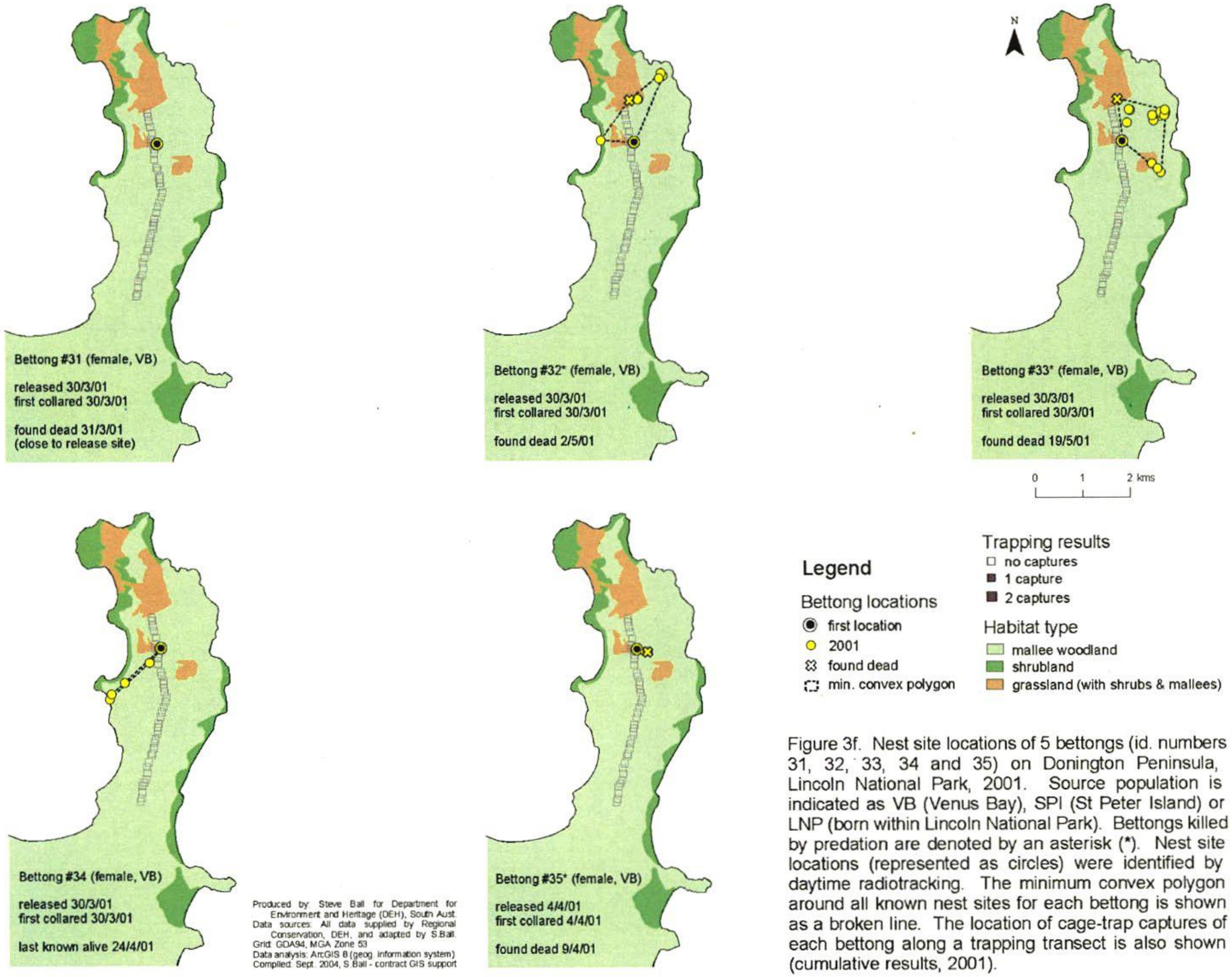


Figure 3f. Nest site locations of 5 bettongs (id. numbers 31, 32, 33, 34 and 35) on Donington Peninsula, Lincoln National Park, 2001. Source population is indicated as VB (Venus Bay), SPI (St Peter Island) or LNP (born within Lincoln National Park). Bettongs killed by predation are denoted by an asterisk (*). Nest site locations (represented as circles) were identified by daytime radiotracking. The minimum convex polygon around all known nest sites for each bettong is shown as a broken line. The location of cage-trap captures of each bettong along a trapping transect is also shown (cumulative results, 2001).

Table 2. Bettong settling time compared among release events.

Release	Source population and date of translocation	Min. settling time (days)	Max. settling time* (days)	Average settling time	Total number settled	% of bettongs which settled within 12 months	Total number with collars
1	VB 6/9/99	7	59	27	12	92	13
2	VB 15/9/99	4	20	17	4	80	5
3	VB 21/11/99	6	9	8	2	50	4
4	VB 30/3/01	13	27	18	4	80	5
5	SPI 4/4/01	16	27	22	2	33	6
Subsequent collaring of released animals before 1.6.01		13	13	13	2	40	5
LNP recruitment		165	165	165	1	10	10 **
All Animals collared after 1/6/2001		40	40	40	1	6.6	16**

*Not including bettongs that took more than 12 months to settle.
**Time to settle could not be determined for 6 animals with faulty collars.
VBCP = Venus Bay Conservation Park
SPI = Saint Peter Island
LNP = Lincoln National Park

Table 3. Average furthest distance moved, dispersal from release area and home range polygon area for male and female bettongs. Sample number in brackets. E = east, W = west, N= north, S = south.

	Average furthest distance moved E or W of release area (m)	Average furthest distance moved N or S of release area (m)	Average dispersal from release area to mean location of nest site records (m)	Average area of polygon surrounding all radio tracking points (ha)
Male	701(13)	1290 (13)	900 (14)	81(14)
Female	777 (35)	1345 (35)	1150 (29)	125 (29)

Table 4. Average dispersal from release area and home range polygon area, compared among releases and for LNP recruits. Sample number in brackets.

Release number	Source and release date	Average area of polygon surrounding all radio tracking points (ha)	Average dispersal from release area to mean location of nest site records (m)
1	VB 6/9/99	319.3 (13)	1410 (13)
2	VB 15/9/99	190.10 (5)	1350 (5)
3	VB 21/11/99	57.11 (10)	700 (9)
4	VB 30/3/01	44.62 (10)	940 (9)
5	SPI 4/4/01	70.29 (5)	630 (5)
LNP recruits	LNP	17.6 (5)	NA

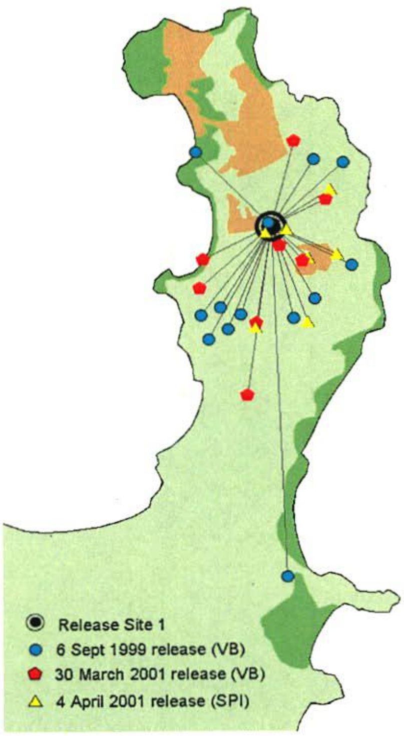


Fig. 4a

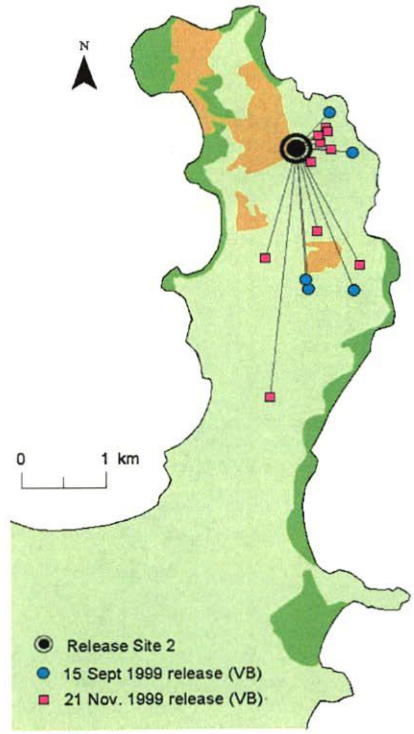


Fig. 4b

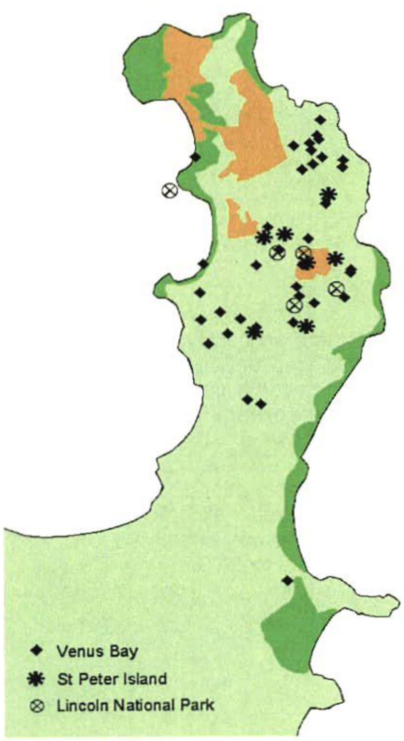


Fig. 4c

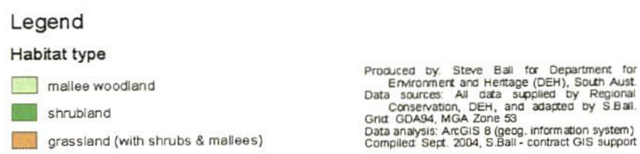


Figure 4. Central location of radiotracked bettongs on Donington Peninsula, Lincoln National Park. The central location for a given bettong is the arithmetic mean (i.e. average easting and northing) of all known nest site locations, based on daytime radiotracking (excluding initial release site and instances when the bettong was in the same nest site as the most recent radiotracking record).

Fig. 4a Net displacement of all bettongs released from Release Site 1. These include two releases sourced from Venus Bay Conservation Park, and one release from St Peter Island.

Fig. 4b Net displacement of all bettongs released from Release Site 2 (all bettongs sourced from Venus Bay Conservation Park).

Fig. 4c Arithmetic mean location of all radio-tracked bettongs released from Venus Bay, St Peter Island, and local recruits from within the Lincoln National Park population.

NB: some locations are placed slightly off Donington Peninsula due to GPS error (and small sample size).

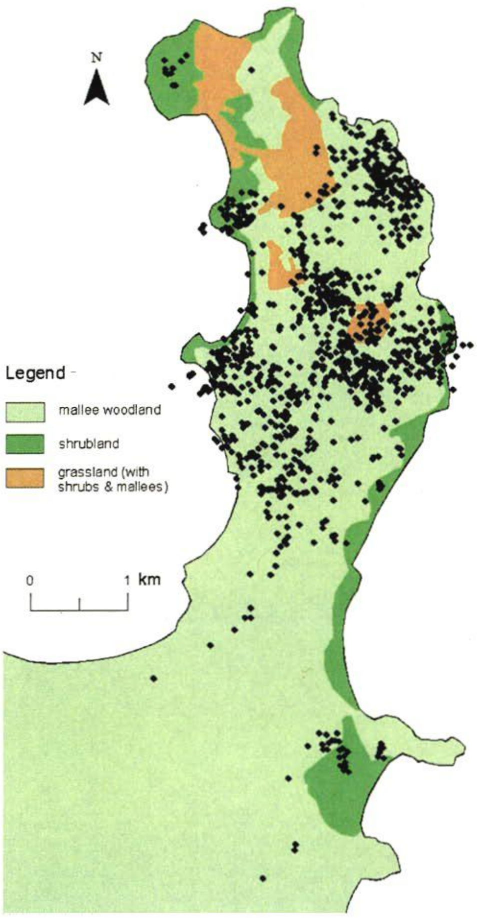


Figure 5a. All known bettong locations on Donington Peninsula, Lincoln National Park, 1999 to 2004. These data include locations recorded during daytime radiotracking of bettongs to nest sites, transect-based cage-trapping, non-transect cage trapping (e.g. cage trapping undertaken to catch and recollar radio-collared bettongs) and discovery of dead bettongs. These locations include both radio-collared and non-collared individuals. NB: some locations are slightly off the Peninsula due to GPS error.

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Data sources: All data supplied by Regional Conservation, DEH, and adapted by S.Ball.
Grid: GDA94, MGA Zone 53
Data analysis: ArcGIS 8 (geog. information system)
Compiled: Sept. 2004, S.Ball - contract GIS support

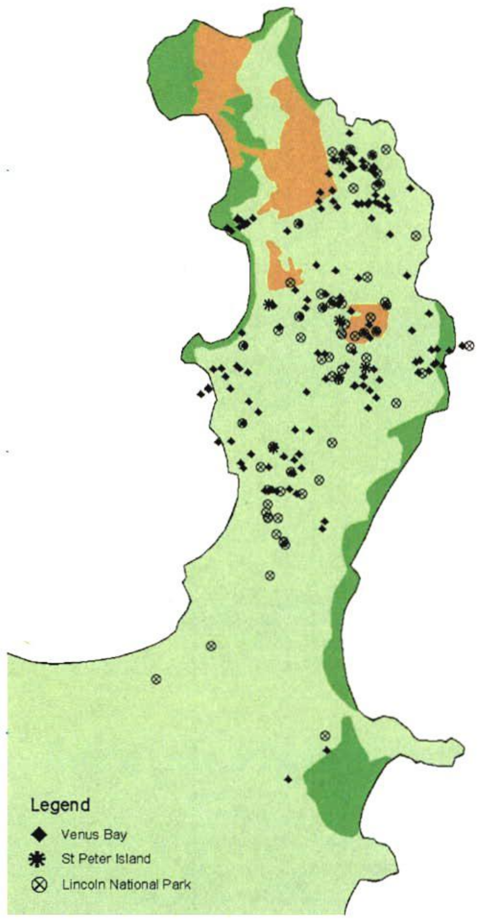

Figure 5b. Locations of all bettongs captured during non-transect cage-trapping on Donington Peninsula, Lincoln National Park, 1999 to 2004. These data were mostly collected when placing traps specifically to catpure and recollar radio-collared bettongs. Therefore, the data are biased towards captures of bettongs collared after release from Venus Bay and St Peter Island. However, there were many instances when non-collared bettongs (from Venus Bay, St Peter Island, and individuals born within Lincoln National Park) were caught in these traps. NB: some locations are slightly off the Peninsula due to GPS error.

Habitat use

Bettongs were found to nest in four broadly different habitat types:

- Open regenerating *Eucalyptus gracilis* or *Eucalyptus conglobata* over an open understorey of *Melaleuca lanceolata* and *Geijera linearifolia, Alyxia buxifolia, Exocarpus sp. Acacia rupicola* and *Acacia cupularis.*
- Open mature *Eucalyptus gracilis* or *Eucalyptus conglobata* over a open understorey of *Melaleuca lanceolata* and *Geijera linearifolia, Alyxia buxifolia, Exocarpus sp. Acacia rupicola* and *Acacia cupularis.*
- Low open patches of *Eucalyptus gracilis* or *Eucalyptus conglobata* over coastal shrubland of *Alyxia buxifolia, Geijera linearifolia* or dense clumps of *Lasiopetalum discolour*
- Low coastal heath dominated by *Melaleuca lanceolata and Melaleuca gibbosa.*

Foraging sites were harder to determine, although evidence of feeding was seen in the form of diggings around the nest sites of some bettongs. Diggings were particularly evident around release area 2, where they were found in sandy soil along with remains of nut grass bulbs (*Gynandriris setifolia*) on which they had been feeding (Stewart, 1999). Targeted trapping (Figure 5b) and spotlight observations also showed that bettongs foraged in and on the edges of grassland areas.

Nest location and use

Bettong nests were often found at the base of *Eucalyptus* trees in thick bark, stick and leaf litter. These shelters were approximately 1m x 0.5 m width and x 0.5 m height and made of tightly packed sticks. Nests were also seen at the base of *Exocarpus* with a dense layer of needle litter, in thick *Melalueca* thickets, near large fallen logs or under stunted *Eucalyptus* in coastal heath. The few bettong nests examined once a bettong had been inadvertantly flushed were formed in a shallow depression, built with sticks and twigs and lined with bark and grass.

Nests were not commonly shared, although a female and juvenile at foot, or an adult male and female, were occasionally found sharing a nest. It was common for a bettong to re-use old nest sites, and bettongs disturbed from a nest often returned to previously used nest sites, some of which had not been used for long periods. Bettongs were generally not observed using nests (current or old) of other bettongs.

Sampling design

The power of the sampling design used for radio tracking bettongs was analysed by Ball (2004)(Appendix 2). Comparison of the importance of sampling size (number of individuals = 5, 10, 20 or 40) verses sampling frequency (confirming each bettong's status every 1, 7, 14 or 28 days), indicated that sample size has a more much marked effect on the quality survival probability estimates than does sampling frequency.

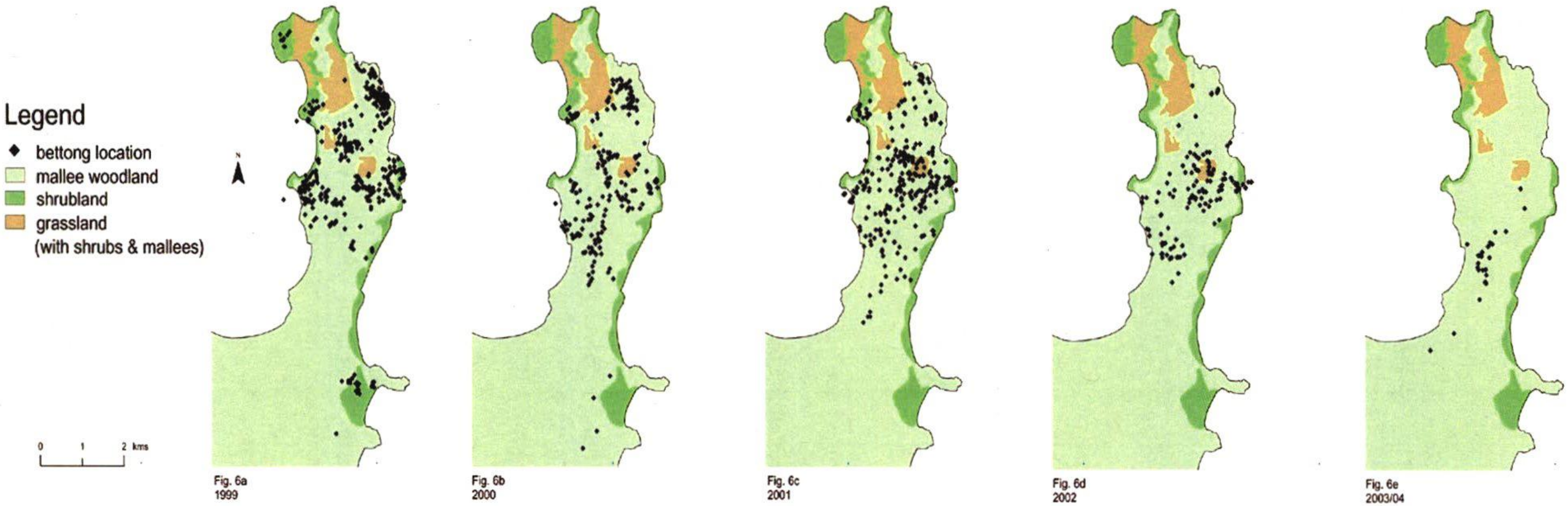

Figure 6. All known bettong locations on Donington Peninsula, Lincoln National Park, arranged by year (1999, 2000, 2001, 2002 and 2003/4). These data include locations recorded during daytime radio tracking of bettongs to nest sites, transect-based cage trapping, non target cage trapping (e.g cage trapping undertaken to catch and recollar radio collared bettongs) and discovery of dead bettongs. The locations include both radio collared and non-collared individuals. NB some locations are slightly off the peninsula due to GPS error.

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Data analysis: ArcGIS 8 (geog. information system)
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5.4 Survivorship

5.4.1 Survivorship analysis

This section summarises the results of the survivorship analysis detailed in Appendix 2 (Ball 2004, Analysis of bettong survivorship in Lincoln National Park 1999-2002).

Monitored bettongs showed a very high survivorship rate in the first 12 months of the reintroduction program, with only one death among radio-collared individuals and an overall yearly survival probability of 0.91 (0.91 = 91% chance of survival).

From Spring 2000, the survival probability of bettongs began to decline, with a three-month survival probability of 0.61. In the 2000/01 summer (coincident with the large Tulka bush fire in late February 2001), survival probability was 0.76. This was followed in Autumn 2001 by the lowest survivorship of the entire study period, with a three-month survival probability of only 0.34. Importantly, this three-month period began with a two additional releases of individuals into the park; 40 bettongs (6 radio-collared) from Venus Bay Conservation Park and 39 bettongs (6 radio collared) from St. Peters Island. Survivorship was particularly low among these newly-released bettongs (0.30 for March 2001 release VB bettongs and 0.01 for the April 2001 SPI bettongs, compared to 0.58 for original 1999 release VB animals).

The bettong population stabilised after a number of peaks in mortality. Although these peaks were followed by concentrated predator control, survivorship remained generally low for the rest of the study period, except for two three-month periods without mortality (Spring 2001 and 2002, survivorship probability = 1.00). While overall yearly (Spring to Winter) survival probability was 0.91 for the first year, it was 0.8 in the second year, and 0.27 in the third year. A low density breeding population of bettongs still remains in LNP

5.4.2 Location of bettong remains

Although dead bettongs were found throughout the monitored area they tended to be concentrated around the original release sites (Fig. 7) and in many cases were found on the edges of vegetation boundaries, in particular the edge of grassland clearings (Fig. 2b).

5.4.3 Cause of death

Examination of teeth marks found on 18 radio collars from dead bettongs concluded that arch shape, intra-arch distance and tooth shape was consistent with *Felis catus* (cat) and not *Vulpes vulpes* (fox) or *Canis familiaris* (dog/dingo)(James et al., 2002, H. James and P. Cirillo, *pers. comm.* 2003). The majority of bettong carcases with cat tooth marks on the collars were freshly killed (collected by monitoring staff within 1 – 2 days), and often found in a state typical of cat predation with head removed and limbs torn from the body. These observations give good reason to conclude that the cats were responsible for 18 bettong deaths. However, in some instances the cause of death was difficult to determine because there were no bites marks left on the collar, no collar present or decomposition was too advanced (Table 5).

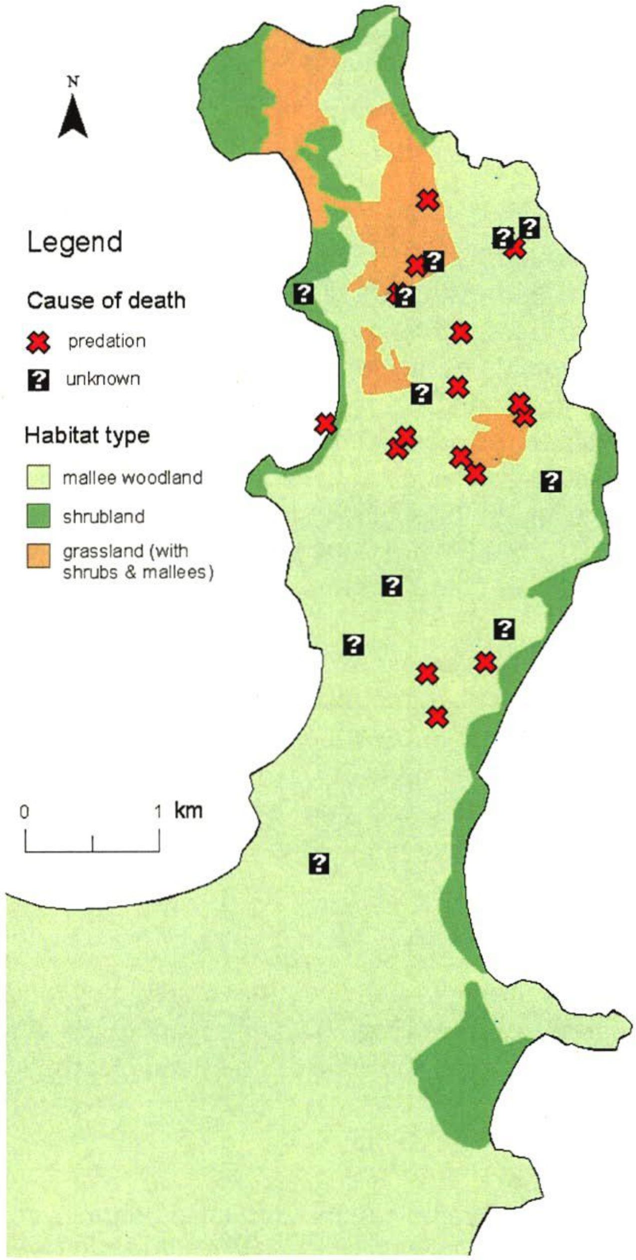

Figure 7. Locations where radio-collared bettongs were found dead on Donington Peninsula, Lincoln National Park, 2000 to 2002. Deaths due to predation (e.g. predator tooth marks identified on radio-collar), are shown as a red cross. Otherwise, cause of death is treated as unknown (no evidence of predation; possibly died due to old-age or disease). NB: some locations are slightly off the Peninsula due to GPS error.

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Data sources: All data supplied by Regional Conservation, DEH, and adapted by S.Ball.
Grid: GDA94, MGA Zone 53
Data analysis: ArcGIS 8 (geog. information system)
Compiled Sept. 2004. S.Ball - contract GIS support

Table 5. Cause of bettong deaths. Predation by cat was assumed when cat teeth marks were found on collars. Death was assumed to be from natural causes when no other likely causes were observed. See Section 5.4.3 for more details.

Release	Cat	Unknown	Management	Natural	Road kill	Total
VB 6/9/99	3	4		2		9
VB 5/9/99	1				1	2
VB 21/11/99	5	2	2 (pouch young)			8
VB 30/3/01	4	2	1(ants)			7
SPI 4/4/01	2	3				5
LNP bred	3		2 (pouch young)			5
Total	18	11	5	2	1	37

5.5 Trapping

5.5.1 Trapping success

Trapping success was highest in the vicinity of the release areas (Fig 6), which had the greatest concentration of bettong nest sites. Trapping success declined in these areas after February 2002. Although all 5 trapping transects were trapped at least once a year, bettongs were only caught on the Donington transect. The number of bettongs caught on this transect has declined since May 2001 (Fig. 8).

Brush-tailed Bettongs are easily caught, and in the majority of cases where traps were set around the nest of a tracked bettong, the individual would be caught. The effectiveness of permanent trapping transects for monitoring bettongs was demonstrated by the regular capture of radio-tracked animals that were known to be near the transect by this method. Throughout the monitoring program only two bettongs showed any sign of consistent trap shyness. The ease of trapping for the majority of the bettongs is supported by instances where the same bettongs were caught on up to four occasions in a two week trapping period, whilst target trapping for other individuals.

Although non-target species were rarely caught in traps, Bush rats (*Rattus fuscipes*), sleepy lizards (*Tiliqua rugosa*), Grey Currawongs (*Strepera versicolor*) and Australian Ravens (*Corvus coronoides*) were the most common non-target species. A rabbit, feral cat and Peninsula Brown Snake (*Pseudonaja inframacula*) were also caught.

5.5.2 Interference

Trap interference by Grey Currawongs and Australian Ravens were first encountered in 2001 but did not impact greatly on the trapping exercise until July 2004 when 15 of the 40 cage traps on the Donington transect were tampered with by corvids. In most cases the hessian had been removed from the trap, and the trap was pulled up to 2 m away from the set location, tipped upside down and bait removed.

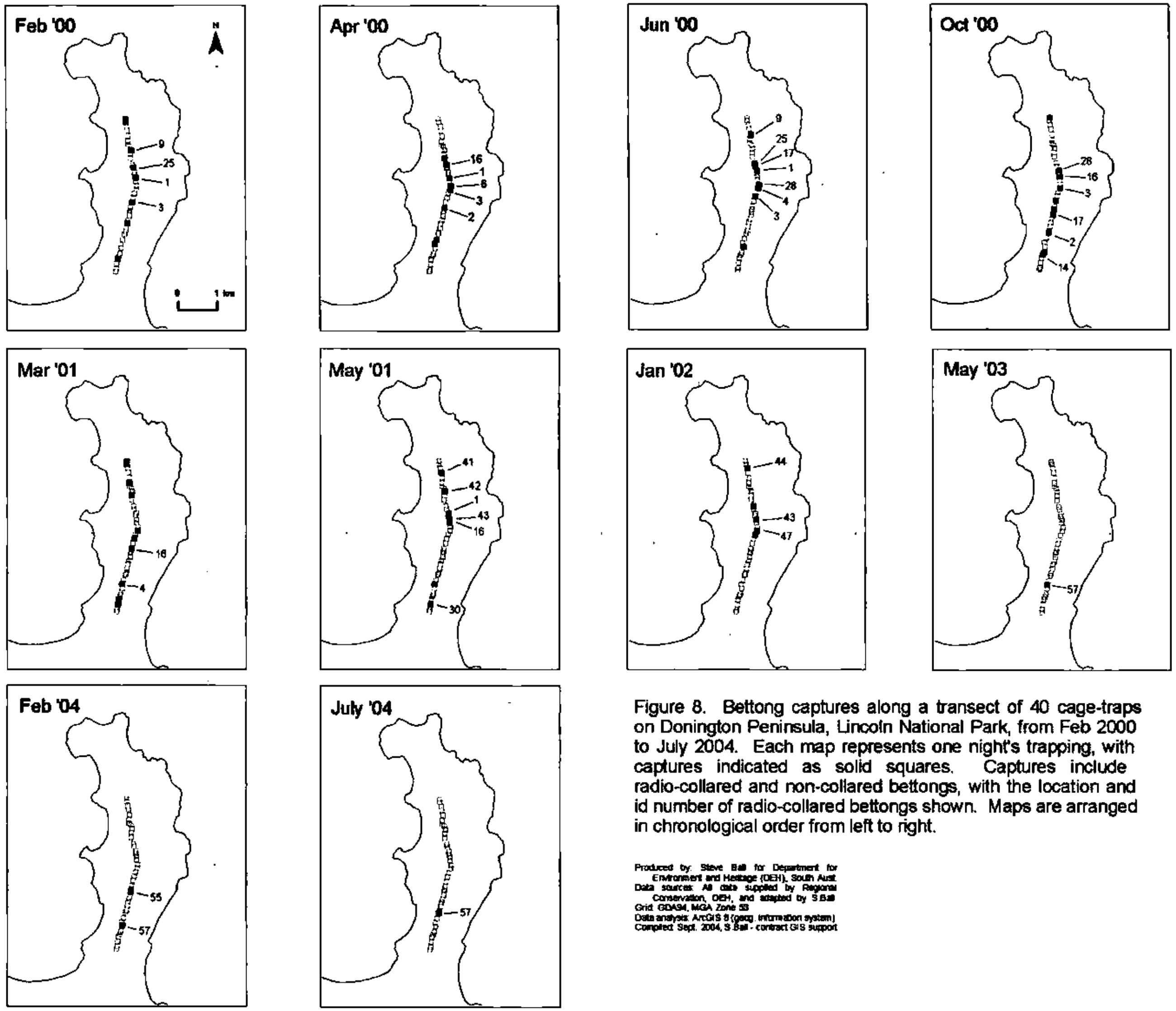

Figure 8. Bettong captures along a transect of 40 cage-traps on Donington Peninsula, Lincoln National Park, from Feb 2000 to July 2004. Each map represents one night's trapping, with captures indicated as solid squares. Captures include radio-collared and non-collared bettongs, with the location and id number of radio-collared bettongs shown. Maps are arranged in chronological order from left to right.

Produced by: Steve Ball for Department for Environment and Heritage (DEH), South Aust
Data sources: All data supplied by Regional Conservation, DEH, and adapted by S Ball
Grid: GDA94, MGA Zone 53
Data analysis: ArcGIS 8 (geog. information system)
Compiled: Sept. 2004, S Ball - contract GIS support

Table 6. Bettong weight gain and loss between each release event, based on bettongs trapped.

Release	Source and date	Average weight gain (g)	No. individuals that gained weight (Percent of total trapped)	Average weight loss (g)	No. individuals that lost weight (Percent of total trapped)
1	VBCP 6/9/99	94	8 (67%)	66	4 (33%)
2	VBCP 15/9/99	15	2 (50%)	100	2 (50%)
3	VBCP 21/11/99	77.5	4 (33%)	77.5	8 (67%)
4	VBCP 30/3/01	30	1 (17%)	33	5 (83%)
5	SPI 4/4/01	107	2 (67%)	80	1 (33%)

Table 7. Weight gain and loss of male and female bettongs.

Sex	Average weight gain (g)	No. individuals that gained weight (Percent of total trapped)	Average weight loss (g)	No. individuals that lost weight (Percent of total trapped)
Female	68.33	12 (63%)	67.14	7 (37%)
Male	153.3	3 (18%)	62.85	14 (82%)

5.5.3 Processing of animals

During trapping events 19 pouch young were ejected. All but three were able to be successfully re-united with the female bettongs, one of which was taken for rearing. The cage return technique for returning larger joeys that were thrown during trapping (section 4.5.2), proved very successful in all cases when used. This method was also useful when returning smaller young to the pouch as it encouraged the female to settle and accept the pouch young and allowed her to leave the cage when ready. Bettong scats collected for analysis whilst trapping indicate that bettongs ingest a range of fungi types in LNP (Lebel T., pers. comm. 2004).

5.5.4 Condition and reproductive success

Although a percentage of individuals from all releases lost weight during the translocation (Table 6), most losses were less than 100 g. Bettongs from release 1 re-gained their weight within several months, whereas it took up to six months for bettongs from successive releases to regain condition. More males lost body weight compared to females (Table 7).

A total of 36 bettongs are known to have recruited into the LNP population between the start of the reintroduction program and July 2004. The first observations of bettong joeys at foot were made between October 1999 and January 2000, when nests of two female bettongs were flushed. The first independent new recruit was trapped on 4th April 2000. Trapping programs have shown that bettongs were in good condition with 85 % of females caught carrying pouch young. The minimum number of known pouch young from trapping records is 112. Breeding was recorded in females from all release events. Bettongs were also found to be carrying young to a late stage of development, with 37 % of all pouch young recorded as medium size (over 5cm) and 18 % as large size (over 10cm).

5.6 Spotlighting and anecdotal observations

Two bettongs were recorded during the first evening of spotlighting along the rabbit oat bait trail in April 2002 and five bettongs were recorded the following evening. Comparison of results from over 25 nights of spotlight survey in the bettong habituated area from 1999 to 2004 show a decline in bettong sightings, beginning in autumn 2001.

Bettongs tracks and scratches were observed by staff whilst radio tracking bettongs and undertaking general park duties in the release area, however few formal records were kept. A single White Bellied Sea Eagle (*Haliaeetus leucogaster*) was recorded as predating on a Brush tailed Bettong in LNP (S. Martin pers. obs). Observations of two bettongs were made whilst undertaking night patrol of the 2001 Tulka fire in LNP, which greatly extended the known distribution of the bettongs in the park (B. Dalzell, S. Martin, pers. obs, 2001). The first bettong was seen at Surfleet car park (53H 587729, 6149551 WGS 84) 3.9 km west and 5.5 km south of the release area. The second bettong was seen half way along Taylors Landing road at a fire break (53H 587700 6142687 WGS 84), 3.9 km west and 12.4 km south of the release area, making this is the furthest distance from the release area recorded for any bettong during the program. No further signs of bettongs have been found in these areas despite subsequent searches and trapping.

5.7 Rainfall

Rainfall recorded for Port Lincoln in the year of the first bettong release (491.4 mm in 1999, Table 8) was 88.9 mm below the annual average of 580.3 mm for this site (Bureau of Meteorology). November and December 1999 were particularly dry, but this did not appear to negatively effect body condition and reproduction of bettongs. Above average rainfall was recorded in 2000, 2001 and 2003, and below average recorded in 2002 (Table 8).

Table 8. Total monthly precipitation for Port Lincoln 1999-2004, recorded from site number 018137. Port Lincoln, West Mere. Sourced from the Bureau of Meteorology, August 2004. Annual = total annual rainfall.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1999	22.0	4.4	55.0	5.4	100.0	66.6	53.0	54.2	56.0	56.4	5.2	13.2	491.4
2000	16.2	42.6	19.2	47.8	69.6	97.0	110.6	103.4	52.2	88.0	5.2	2.4	654.2
2001	1.2	26.0	42.8	15.0	89.8	81.1	74.4	71.2	88.8	58.6	41.2	54.0	624.5
2002	13.4	1.8	17.2	14.4	80.0	115.0	65.6	60.4	47.6	54.0	30.4	23.2	523.0
2003	42.2	33.0	6.2	11.6	71.8	103.0	70.6	133.0	46.6	64.0	19.8	20.8	622.6
2004	8.0	2.8	40.2	27.0	58.2	87.8	85.8						

5.8 Effectiveness of threat abatement

Foxes

Quarterly saturation fox baiting throughout LNP and opportunistic baiting carried out during park management duties has dramatically reduced fox numbers since 1998 (Tilley, J., pers. comm., 2003). LNP Bush-stone Curlew (BSC) surveys from 2000 to 2004 showed increased numbers and breeding success (with chicks recorded) of BSC, indicating effective fox control. In addition, spotlighting, bait station surveys and observations made by staff and volunteers undertaking predator trapping showed no evidence of foxes in the early stages of the release program. However, an increase in fox tracks was noted following the Feburary 2001 bushfire and during Summer 2002. Extra fox baiting was undertaken as a result.

Rabbits
The effectiveness of rabbit control techniques was not measured, although anecdotal observations indicated that rabbit numbers decreased after baiting and warren ripping.

Cats
An increase in cats was observed in LNP following successful fox control. In May 2001, 2 feral cats were caught using leg hold traps over a period of 20 trap nights. Leg hold traps were set over summer of 2001/2002 without success. No cats were caught by the Sporting Shooters Association in July 2001 and May 2003 despite over eight days of trapping and 7 nights of spotlighting effort.

5.9 Financial and human resources

Details of costs incurred during reintroduction, monitoring and evaluation are summarised in Appendix 3. The total cost of the reintroduction program (January 1999 to August 2004) was $144,176. This amount includes targeted threat abatement within the bettong release area, yet excludes on-going park-wide predator control, as the latter is considered to be a general park operation cost.

Contractor wages, travel & accommodation	$ 57,696
DEH staff wages	$ 38,586
DEH vehicles and fuel	$ 11,383
Trapping equipment / expenses	$ 2,858
Collaring equipment / expenses	$ 29,324
Target threat abatement in bettong area	$ 4,331

Grants were sought and granted by the following sources:

June 2000	Nature Foundation SA Inc.	$ 2,500
July 2001	Wildlife Conservation Fund	$ 2,565
July 2001	Nature Foundation SA Inc.	$ 3,164
June 2001	Wildlife Conservation Fund	$ 1,710
April 2001	Tulka fire reinstatement	$ 20,000
2001	DEH Directors grant	$ 1,000
2002	NHT Biodiversity Grant	$ 300
2002	NHT Fox Baiting Grant	$ 400
	Total	$31,639

A total of 6376 person hours were spent on the program between January 1999 and August 2004, consisting of 2398 contractor hours, 2228 staff hours and 1750 volunteer hours, contributed by 57 volunteers.

5.10 Community involvement

The bettong reintroduction program was very successful in raising awareness of DEH conservation objectives in the general community with increased volunteer and business support. Awareness of and involvement in the LNP bettong reintroduction program has encouraged the local community to appreciate and support efforts to undertake ecological restoration programs on the Eyre Peninsula. This is illustrated by an increase in membership of two local Friends of Park groups and general volunteers, local school and business interest to assist with conservation programs including, Yellow-tailed Black Cockatoo monitoring, malleefowl monitoring and reintroduction to LNP, animal surveys, pest and weed control, and sheoak-woodland restoration work. Local newspaper publishers, radio and television stations have also dedicated numerous articles and stories to the progress of the bettong reintroduction program. Successful integrated pest control in LNP and VBCP and the establishment of bettong populations in both parks, have been factors in promoting the adoption of integrated pest management practices by a rapidly growing number of farmers across the Eyre Peninsula.

6. Discussion

6.1 Has the release been successful?

At the time of writing, the reintroduction program has succeeded in establishing a breeding population of Brush-tailed Bettongs in Lincoln National Park. Therefore the Lincoln National Park reintroduction is currently the only successful Australian mainland release of Brush-tailed Bettongs outside of Western Australia, without predator-proof fencing. Three other attempts have been made to reintroduce Brush-tailed Bettongs to the Australian mainland without predator fencing and outside of Western Australia (Katarapko Island River Murray SA, Flinders Ranges SA and Yathong Nature Reserve, NSW). The LNP bettong reintroduction is the only such program with a breeding population still in existence 5 years after bettongs were first released. No bettongs are known to have survived from the other three releases. However, the ongoing decline in bettong density in LNP is a concern, and it is unknown whether this will result in the extinction of the population, or whether the population will continue to persist at low densities. Sinclair *et al.* (1998) suggest that when *B. penicillata* occurs at low numbers this species has a refuge from predators. Therefore it may be expected that if bettongs persist in LNP it will be at low numbers only, unless predation by cats and foxes is removed altogether.

The translocation method adopted for the LNP reintroduction was also very successful, with only one adult bettongs from 113 not surviving the translocation. Many of the translocated animals maintained there weights or increased weight after a period of settling. The majority of radio-monitored bettongs also maintained stable home ranges.

Involvement of local media and conservation volunteers in the LNP bettong program has engaged the local community, raising community awareness of and advocacy for DEH conservation objectives. This is highlighted by the growing number of volunteers, local school and businesses actively participating in ecological restoration projects across the Eyre Peninsula. Assistance sought for supply of materials and services for the bettong program, and to promote community awareness and involvement has also formed good working relations between DEH and industry. Relations with local media have benefited in particular, with media organisations keen to work closely and cooperatively with DEH on conservation issues.

The LNP bettong reintroduction program has helped support other reintroduction programs (such as mallee-fowl into LNP) as part of a larger ecological restoration program on Lower Eyre Peninsula. Successful pest management and conservation works in parks such as

LNP, Coffin Bay National Park and Venus Bay National Park have also encouraged neighbouring landholders to adopt integrated pest management practices for increased farm productivity and biodiversity benefits. Integrated Pest Management focuses on controlling vertebrate pests by coordinating effort and sharing knowledge and resources between reserves, farms and Animal and Plant Control Board areas.

6.2 What can we learn from this reintroduction to inform future management of bettongs in LNP, and bettong reintroductions elsewhere?

6.2.1 Release strategy

The first bettong translocation was undertaken in Spring 1999. Spring is recommended as an ideal time to release Brush-tailed Bettongs, as foxes are denning and weather conditions are optimal. This gives the bettongs several months to establish before fox cubs disperse in late Summer (Start et al. 1995) and adolescent feral cats begin to hunt independently in Summer and Winter (Cunningham, D., *pers. comm.* 2004). The fourth and fifth bettong releases in LNP, however, occurred in Autumn 2001. High incidences of cat predation in late Autumn were recorded for LNP in 2001, 2002 and 2003. Patterns of increase in cat activity in late Autumn and early Winter in semi arid and drier temperate areas are well supported in other studies, including feral cat research work at Lake Burrendong in Central New South Wales (Molsher, 2001) and bettong reintroduction projects at Yathong Nature Reserve, Western New South Wales (Priddel and Wheeler, 2003) and Venus Bay Conservation Park, West Coast of South Australia (Armstrong, D. *pers. comm.* 2004).

- **Recommendation 1:** Future bettong reintroductions in LNP or similar habitats should not be undertaken in late autumn / early winter.

The LNP bettong reintroduction program was made up of 5 release events. Mc Callum *et al* (1995), however, suggest that in almost all circumstances a single reintroduction is preferable to several smaller ones. Comparison of 116 reintroduction case studies made by Fischer and Lindenmayer (2000), also found an overall increase in success when a larger number of animals were released, and that releasing approximately 100 individuals led to a higher success rate than releasing fewer individuals. However, Short *et al*, (1992) emphasise that increasing the size of the released group is no substitute for effective identification and management of factors limiting the population (chiefly predation).

- **Recommendation 2:** Large numbers of animals should be simultaneously released in future bettong reintroductions.
- **Recommendation 3:** Future bettongs reintroductions need to incorporate a high level of integrated pest management before and after release events.

6.2.2 Bettong, movement, condition and reproduction

Movement

Stewart (1999) noted that comparisons between the movement behaviour of male and female bettongs are difficult to make, due to different sample sizes and timing of releases. However, the average distances recorded in this study indicate that females tended to move further from the release site and range more widely than males. The slightly larger distances moved by the first release females is likely to be due to these bettongs being the first in the park. The females would have experienced an area devoid of bettong activity, whereas males were released into an environment which was marked / scented by other bettongs. Previous experience with Brush-tailed Bettongs in VBCP, Greater Bilbies *Macrotis lagotis* on Wedge Island and Greater Stick- nest Rats *Leporillus conditor* on Reevesby Island, have found that when the males are released first, they tend to move further than the females (Stewart, 1999). Release of a greater number of females, or the release of females before males, appears to be a useful procedure to follow if managers wish to contain the initial spread of released animals.

The February 2001 fire burnt only a small area of known bettong habitat in the park, therefore few home ranges would likely to have been disturbed by loss of vegetation due to fire. It is believed bettongs are more likely to have been affected by implications after fire, such as increased predator densities (Van Weenan, Copley, 2004, pers. comm).

Observations of bettong deaths in LNP, show that from Summer 2001 predator pressure was concentrated on the release areas. These areas remained vacant of bettongs well after predator pressure declined.

Christensen (1980) noted that in relation to fire studies, woylies have a very high home range fidelity. Bettongs were reluctant to move from burnt-out home range areas, and any moves were made very slowly with a gradual extension of home range areas by limited exploration. The high home range fidelity of bettongs, may then explain the absence of bettongs in the now vacant home ranges around the release areas. Alternately, these territories may be no longer suitable due to increased predator activity and/or declines in food availability and quality.

The influence of increased predator pressure is likely to be the reason for only one monitored bettong being recorded as settled after June 2001. This individual was settled for a short period in November 2001, then moved irregularly before it was killed by a feral cat in July 2002. Noticeably only one of the monitored new LNP recruits were ever recorded as settled, perhaps because of continued low level predation within the park, or inability to find suitable habitat for territories.

Figure 4c and table 4 illustrate that VB bettongs moved further out than SPI bettongs. The increased distance moved by VBCP sourced bettongs may be explained by their rapid adaptation to habitat of LNP that has a similar vegetation structure to VBCP. VBCP bettongs were also derived from wild WA bettongs and a small number of the original wild bettongs were translocated from VBCP to LNP. SPI bettongs on the other hand came from a vastly different island habitat and originated from captive bred stock.

Figure 4B also suggests that VB bettongs move further than the LNP recruits, but with reference to trapping information in figure 5b, LNP recruits can be seen to cover more of the Donington Peninsula than tracking data first suggests. This highlights the importance of analysing both trap and radio monitoring records.

New LNP recruits were found further south along the Donington Peninsula, in new "unclaimed" territories. Interestingly the LNP recruits have not dispersed as far as may have been expected within the four years of population establishment. This may be due to availability of suitable habitat in the top end of the Donington Peninsula

- **Recommendation 4:** Continue monitoring of the trapping transects and opportunistic trapping throughout the park to establish patterns in dispersal.

Results from previous bettong studies on South Australian island populations and in the Flinders Ranges on the mainland, show that release of additional animals can be a problem, with newly released bettongs forced to inhabit less favourable areas (e.g exposed grassland). Subsequent bettong releases to LNP did not seem to obviously displace existing bettongs, or force new bettongs into exposed sites, as large areas of suitable habitat were thought to exist (van Weenan, 2004, pers. comm.). However, some variations in habitat quality that did influence bettong survival may have been difficult to detect (see section 6.2.6).

Condition and reproduction

Body weight can be an indication of bettong health, but it is important to recognise that fluctuations in body weight are likely to follow seasonal conditions, resources, intra-species competition, habitat variation, predator pressure and importantly pouch young. Feeling body condition and noting the presence of parasites were therefore also useful indicators of bettong health in this study. Female bettongs released into LNP were better able to maintain their body weight than males, which was also observed by Bellchambers (2001) during the reintroduction of Brush-tailed Bettongs into Flinders Ranges National Park.

Trap records show LNP bettongs were able to maintain or regain body weight /condition after release and were breeding and recruiting well. In comparison, Priddel and Wheeler (2003) recorded no pouch young greater than 50 mm length during the Yathong Nature Reserve bettong reintroduction. Female bettongs failed to carry pouch young to full term, with no young at foot observed during the project.

Bellchambers (2001) reported 3 known weanings of pouch young and only 2 independent young trapped during the Flinders Ranges National Park bettong reintroduction. Most females were carrying only small and medium sized young each time trapped, and the interval between trapping was not long enough for previous young to have grown to a size that it could vacate the pouch. No female bettongs were observed to have pouch young more than 50 mm in length.

The greatest number of independent young in LNP were first captured in 2000 and 2001 (14 and 10 young respectively). Six independent young were first trapped in 2002 and 2003. The higher rainfall recorded in 2000 and 2001 may have contributed to the increase in recruitment, as bettong joeys are more likely to survive to weaning if there is sufficient nutrient resources to support both the female and pouch young (Bellchambers, 2001).

6.2.3 Bettong mortality and survivorship

Although remains of radio-collared bettongs were found spread across Donington Peninsula and throughout all general habitat types, at least nine dead bettongs were located on the edge of vegetation boundaries between open woodland and grassland. Bettongs had often been observed foraging in the grasslands at night, where in the open ground they were likely to have been easier targets for predators. Concentrated predator control in these areas is an obvious priority. It may also be useful to investigate what made the grasslands a preferred foraging area and to manipulate the vegetation to provide good foraging areas near good cover.

Individuals from SPI died much sooner than the VB animals and LNP recruits monitored. This pattern was also noted during reintroduction programs at Yathong Nature Reserve (Priddel & Wheeler, 2003) and Flinders Ranges National Park (Bellchambers, 2001), where bettongs were also sourced from SPI and VBCP. However, the SPI animals in the Yathong reintroduction appeared to die from starvation or physiological stress associated with transportation (Priddel & Wheeler, 2003). This was not the case with SPI bettongs at LNP, where most SPI bettongs gained weight after release. In LNP the cause of death of the SPI bettongs was more likely to be due to predation and predator naivety, as suggested by Bellchambers (2001) for the Flinders Ranges release. Furthermore, in all three bettong reintroduction programs, animals from every source location were predated. Although some level of predation is to be expected, this may also imply that the source populations had little experience of predation in general and mammalian predators in particular (Bellchambers, 2001, Priddel & Wheeler, 2003).

Bettong survivorship began to decline in Spring 2000, reached its lowest level in Autumn 2001, and remained low for the rest of the study period. As previously discussed (Appendix 2) the low Autumn 2001 survival probability was probably strongly influenced by naïve bettongs from releases 4 and 5 suffering higher mortality than previously-released bettongs, and also may have been influenced by the less intensive predator and rabbit control undertaken prior to releases 4 and 5. The following 3 theories (which are not necessarily mutually exclusive) are postulated to explain the general pattern of decline that commenced in Spring 2000:

1. Cats were already present in LNP when bettongs were first released, but did not learn how to find and hunt bettongs effectively until Spring 2000. Furthermore:

- The presence of 'predator naive' bettongs from releases 4 and 5 may have allowed cats to improve their capture technique until they were able to outsmart and catch original bettongs released in 1999. (Freak et al, 2001).
- Bettongs exhibit a high home range fidelity (Christensen, 1980), and bettongs may have been unable to change their home ranges to avoid predation even when feral cats began to concentrate hunting in high density bettong sites (release areas).

2. Cat abundance increased in LNP in Spring 2000 and remained high throughout the study period. This may have been facilitated by:

- Fox control measures successfully reducing fox numbers and providing an opening for other predators, namely feral cats ('mesopredator release' *sensu* Soulé *et al.* 1988). The timing of the decline in bettong survival probability may indicate that cat activity increased some time after fox control commenced. Priddel and Wheeler (2003) suggest that the removal of foxes may have exposed the Yathong Nature Reserve to increased predation from feral cats, and fox control may simply replace one devastating feral with another.
- Displacement of cats to the unburnt area of Donington Peninsula following the February 2001 fire.
- Increased rabbit numbers in Spring 2000 and early Summer 2001, following high rainfall in 2000, which may have inflated cat numbers during their breeding season. Newly independent juvenile cats contributed extra hunting pressure when dispersing in Autumn and Winter 2001.

3. The abundance of bettong food resources declined after the first 12 months of the release. This resulted in bettongs having to spend more time finding food and/or being

forced further away from cover to find food, and this increased their vulnerability to predation.

- **Recommendation 5:** Use animals with some notion of predator awareness for future reintroductions.
- **Recommendation 6:** Control foxes, cats and rabbits before bettong reintroduction and maintain low densities of these animals for the life of the program. Concentrate control efforts at times of release, increased predator or prey breeding, natural disturbances such as fire, and focus efforts on vegetation boundaries.
- **Recommendation 7:** Allow native vegetation to regenerate by reducing grazing pressure by kangaroos and rabbits.
- **Recommendation 8:** Conduct prescribed burns with the aim of increasing the suitability of habitat and availability of food for bettongs.

Despite high bettong mortality during the program, some individual bettongs managed to avoid predation for several years. A capture was made of a seven-year-old female (originally tagged in VBCP in December 1997 and released in LNP in September 1999) in good condition and carrying pouch young in May 2004. This is very positive when the average life expectancy of bettongs in the wild is recorded to be 4 to 6 years (Christensen, 1983). Three other bettongs released in September 1999 were also radio tracked constantly for three years. In comparison, all animals in the Yathong bettong reintroduction died within 13 months and those in the Flinders Ranges reintroduction died within 21 months of release (Priddel & Wheeler, 2003, Bellchambers, 2001).

The service provided by the Forensic Odontology Unit proved extremely useful in identifying predator species.

- **Recommendation 9**: Continue to engage the Forensic Odontology Unit to identify cause of bettong death when predators are involved.

6.2.4 Monitoring techniques

Radio tracking

For detailed records of bettong movement and survivorship radio tracking is one of the most effective, with ground tracking found to be adequate. The efficiency of aerial searching, however, was also demonstrated on several occasions.

Analysis of radio-tracking data has shown that a large sample size is more important than a large sample frequency for estimating survival probability. A minimum of 10 and ideally 20 monitored bettongs are needed to provide data to confidently indicate changes in bettong survivorship. In order to estimate three-month survival probability it was found sufficient to monitor every 14- 28 days. It is recommended, however, that both sample frequency and sample size be increased if survival estimates are required over a smaller time interval or with more confidence (Appendix 2).

The brass band loop collars used during the LNP bettong monitoring rubbed on the necks of several bettongs causing injury. Similar problems with this style of collar were reported by Bellchambers (2001) and Priddel and Wheeler (2003). Staff and contractors involved in the LNP study can easily relate to Bellchambers (2001), who noted "the variable quality of the tune loop telemetry packages used in the initial release was a source of frustration throughout the first year of the study". Bellchambers (2001) changed to a single stage whip aerial transmitter on strengthened plastic collars with 12-month batteries, supplied by *Sir Track*, NZ. These gave better signal strength and battery life. They feature a durable flexible plastic collar material that caused no injuries to bettong necks. Although *Titley* collars were employed during the later stages of the LNP study, these lacked signal strength of the original *Biotelemetry Tracking* collars.

- **Recommendation 10**: *Sir Track* whip collars, (used with proven success in the Flinders Ranges Bettong Reintroduction program) (Bellchambers, 2001), be used for bettong monitoring in preference to the brass band loop collars.

Problems encountered with reliability of radio-tracking collars can explain the low number of tracking records made for some bettongs.

Trapping

Trapping is critical to assess bettong condition and reproductive status. Trapping is also the most effective and time efficient method of positively identifying the presence of bettongs, as they are very easy to trap. However, the trapping transects only sample a small area of LNP, and do not sample some areas of LNP, into which the bettongs may have dispersed, that are very difficult to access for trapping.

- **Recommendation 11**: Allocate time to trap some of the more difficult terrain of LNP, and actively search for bettong activity (tracks, scats and diggings).

Another method of detecting bettong presence is the identification of hair collected in hair tubes. Hair tubes have not been used in this program to date. Some drawbacks of this method are that a high level of skill and experience is required to accurately identify hair (Lobert et al, 2001), and that reptiles can be trapped in these devices (van Weenan pers. comm., 2004, Lobert et al. 2001). However, hair tubes are easier to transport to the more inaccessible parts of LNP, may not need to be checked as frequently as cage traps, and can be left out for several nights, increasing the chance of being detected by bettongs.

- **Recommendation 12**: Investigate the use of hair tubes for bettong detection and monitoring.

Interference of traps by corvids became a major issue in mid 2004. Traps should be pegged down in areas where these problems are encountered.

All five LNP trapping transects are undertaken annually and ideally the Donington transect should be trapped quarterly. Although trapping of the Donington transect has not occurred consistently on a quarterly basis, the trapping data collected still provides a good comparison of bettong presence in the Donington area over time.

- **Recommendation 13:** conduct quarterly trapping of the Donington and Taylor's Landing trap transects if radio tracking is no longer used to monitor bettongs.

Processing of animals

During the November 1999 a single stitch was applied to the pouch of a female bettong to prevent the young from being thrown, yet the female threw the joey when released in LNP.

- **Recommendation 14**: Use more than one stitch, if stitches are used to contain pouch young, or use the less disruptive trap return method of uniting young with female (Inns B. & van Weenan, J., pers. comm. 2004).

Collection of scats for scat analysis has only been undertaken on a few occasions during bettong trapping events in LNP. The value of scat analysis to determine bettong diet was highlighted by Bellchambers (2001). Lebel (2001) and Lee (2001) also support the use of bettong scat analysis to identify hypogeous fungal (truffle) assemblages. Preliminary studies of bettong scats by Lebel (pers. comm, 2004) suggest interesting truffle finds for LNP, highlighting potential research studies in this area.

- **Recommendation 15**: Collect bettong scats whenever possible and forward to Teresa Lebel, Melbourne Herbarium, for analysis.

Spotlighting and anecdotal observations of bettongs

Spotlighting for bettongs whilst carrying out feral predator surveys resulted in two bettongs sighted in one evening. The best spotlighting result for bettongs, though, was recorded after an oat bait trail laid for rabbit control. Spotlighting for bettongs with use of oat trails has also been used with great success on several occasions in Venus Bay Conservation Park (Stelman, J., pers. comm., 2002).

- **Recommendation 16**: Trial the use of oat bait trails in LNP to detect presence of bettongs, and/or survey opportunistically for bettongs if baiting rabbits.

Predation of bettongs by Wedge- tail Eagles (*Aquila audax*) is recorded by Priddel and Wheeler (2003) and Bellchambers (2001). Although Wedge- tail Eagles were not recorded as a predator species in LNP, a White Bellied sea eagle was observed taking a bettong. It is not suspected that birds of prey have a large impact on the LNP bettong population.

Bettong tracks and diggings are easy to differentiate from diggings of other mammals present in LNP (Triggs, 1996), and records of bettong feeding activity and tracks were often observed during radio tracking and trapping exercises. Consistent and conscientious formal records of these activities were unfortunately not made. This may have been a result of numerous staff and contractors involved in monitoring over the four year study period. These records are just as important as trap and radio-tracking records and emphasis on intensive searching and recording of signs of bettong activity is essential in any reintroduction program (Young, M, *pers. comm.*, 2004).

- **Recommendation 17**: Train staff to identify signs of bettong activity and prepare a specific datasheet to encourage formal recording.

6.2.5 Resources and technical skills required

This study highlights the need to clearly identify resource requirements and sources for any translocation proposal. Without the grant funding which was obtained the success of the LNP bettong project would have been dramatically compromised. The DEH Eyre District budget would simply not have been able to deliver human resource requirements or meet equipment costs associated with the reintroduction. Although very fortunate to receive the additional grant funding, it is not good to rely on grant funding, as it is impossible to ensure that you will be successful in securing any (van Weenan, pers.comm, 2004). Local DEH staff were expected to take on the extra work associated with the reintroduction in addition to their already substantial pre-reintroduction workloads. Involvement in the reintroduction program was seen as a priority, and may not have had a large impact, until problems were encountered (e.g. increased predation) and extra time needed to be spent on the project. Assistance provided by contractors and volunteers was crucial to the success of the program. The use of university students, trained conservation volunteers and DEH staff from other districts may be necessary to meet the current monitoring recommendations for

LNP bettong population. This should be promoted as a training opportunity and valuable work experience in reintroduction programs.

- **Recommendation 18**: Involve students, volunteers and DEH staff from other districts in bettong monitoring and releases.

Detailed records of costs associated with the reintroduction program were not kept on a central budget spreadsheet / in a central location. This made collation of human resource and equipment costs for this report very time consuming.

- **Recommendation 19**: Keep accurate and up to date records of budgets, costs and labour effort.

Although nest site habitat data was collected during radio tracking in LNP, vegetation information recorded was unfortunately very basic. Detailed analysis of nest site selection was therefore not possible in this study.

- **Recommendation 20**: Develop or adopt vegetation classification codes and provide staff with training in vegetation identification to ensure that more detailed habitat records are taken.

6.2.6 Threat abatement

Foxes

Predator surveys, bait uptake, and Bush Stone-Curlew surveys all indicated that fox control was effective in LNP during the study period. In addition, none of the known bettongs deaths in LNP could be positively linked to fox predation, whereas, fox predation attributed to 75% of known deaths during the Flinders Ranges bettong release program (Bellchambers, 2001). Experimentation with a mix of bait types is likely to have increased bait uptake by foxes. Young (pers.com. 2004) recommends planning fox baiting events around moisture availability / rainfall for best uptake. Use of wet baits in summer in LNP has given the best results during drier conditions (Tilley, J., pers. comm., 2003). A greater understanding of predator moisture requirements may assist in improved predator control (Young, M, pers.comm, 2004).

- **Recommendation 21:** Continue to use quarterly 1080 baiting to control foxes, use a variety of meat baits, and plan baiting around rainfall events if possible to increase uptake and extend bait life.

Spotlight predator surveys have been underfaken quarterly for the last 3 years, yet the usefulness of this method to detect and control foxes must be questioned. Most (5/8) of the transect tracks traversed are through thick vegetation, which provides good cover for foxes and therefore greatly reduces the likelihood of predator sightings or opportunities to shoot.

Rabbits

Baiting and warren ripping appeared to be effective means of rabbit control in LNP, although this was not measured. No records of the number of warrens blasted were kept and follow-up blasting after the February 2002 warren mapping did not occur. The expense of explosives is also a major impediment to rabbit control.

- **Recommendation 22:** Conduct annual or biannual rabbit baiting of Donnington Peninsula, in combination with warren mapping and blasting as needed.
- **Recommendation 23:** Source funds to purchase explosives for warren destruction.

- **Recommendation 24:** Keep accurate records of warren locations and details of timing and nature of control methods used.

Cats

Feral cats were identified as the major predator of bettongs in LNP, with at least 49% of the known bettong deaths to attributed to feral cats. Cat predation was also a major factor in the failure of a bettong reintroduction to Yathong Nature Reserve in 1999, where 74% of bettongs taken by predators were killed by feral cats, and all bettongs were dead within 13 months (Priddel and Wheeler, 2003).

Molsher (2001) notes that cats are notoriously difficult to trap, do not take baits readily and bait visitation and ingestion rates area usually low. These finding were supported by the limited success of cat control attempts in LNP. As mentioned above, spotlight surveys aimed at monitoring and controlling both foxes and cats in LNP were of limited use, with only a few sighting and no shootings. Much of the transect track was through thick vegetation, providing ideal cover for feral cats which are very hard to flush from heavy cover (Skeates, M, pers. comm., 2003).

Intensive trapping with leg-hold traps did result in capture of several feral cats, yet days of trapping with cage traps and ecotraps failed to result in any captures. Caution must also be taken with using leg hold traps, as Bellchambers (2001) found one bettong severely injured in a trap set to trap feral cats. Armstrong (pers. comm. 2004) also highlights the danger of catching non target species in leg hold traps, informing that "bettongs are very curious and can also be attracted to meat baits used for fox and cat control / trapping". Moseby et al, (2004) suggest short fences made of wire netting and placed around leg-hold traps may be useful in deterring non-target species.

Cats are unable to be legally baited with poison in SA and so any bait must be used in conjunction with traps. Bait trapping for cats is of limited value if other food resources are plentiful (including rabbits). Studies also indicate that the best time to target trap cats is late autumn and early winter, using baits that reflect the staple prey of cats in the particular area (Molsher, 2001). As for foxes, the availability of moisture may have an influence on the success of using poison baits or baited traps to control cats. Cat have been reported to bite the heads off bettongs to obtain moisture in Venus Bay CP (Mike Young, 2004, pers. comm). Investigations into the moisture requirements of cats may lead to increased success of control methods. Moseby et al (2004) found that auditory lures had advantages over olfactory or food lures for trapping feral cats for the Arid Recovery Project at Roxby Downs, SA. Auditory lures were easier to transport and maintain, provided a consistent output regardless of time and weather conditions, and did not require continual replenishment (Moseby *et al.* 2004). Andrew Freeman (pers. comm. 2004) also recommends trialing lure traps in LNP, which are fitted with radio transmitters, and can be checked remotely via a radio telemetry receiver.

- **Recommendation 25:** Investigate the effectiveness of traps baited with lures to control cats.

Suitability of habitat for bettongs at the release site

The LNP release site was deemed to have habitat suitable for bettongs apparently because Brush-tailed Bettongs have been successfully reintroduced to a range of similar habitats in South Australia. However, this rationale overlooks the fact that bettongs have been successfully reintroduced and maintained at these other sites (except for VBCP) in the absence of cats and foxes. And although the bettongs at Venus Bay CP currently co-exist with a number of cats within the fenced area (D. Armstrong pers. comm.), cat densities were apparently low when bettongs were originally reintroduced.

When assessing the suitability of a site for bettong reintroduction, several aspects of habitat quality (i.e. the amount and distribution cover, food, and the nutritional quality of food) need to be considered in combination with the amount of predator activity. Bettongs may be able to survive in poor habitats with little cover and limited supplies of low nutrient foods if their foraging time is not restricted by the activity of predators. Foraging time would simply be increased to satisfy diet requirements, although there would be a critical threshold at which foraging time would not be sufficient to gather the minimum amount of food required. However, once bettongs need to spend time avoiding predators, this would curtail the time available for foraging, and the amount and distribution of cover becomes far more important. Consequently, where predators are present, bettongs would only be able to survive in better quality habitats, where the abundance and distribution of cover, food and nutrients are above certain critical thresholds.

Unfortunately, critical habitat thresholds for bettongs have not yet been identified, although perhaps educated guesses can be made if known aspects of bettong biology are considered. However, even if thresholds become known, measurement may remain problematic. Although it may be relatively straightforward to estimate cover or number of potential nest sites in a given area, measuring the abundance and distribution of bettong food in the field is notoriously difficult (T. Lebel and S. Carthew, pers.comm.2004). Therefore an alternative strategy may be to restore the habitat conditions known to be present before bettongs originally became extinct at a particular site.

Since European settlement the vegetation and soils of LNP have been modified by altered fire regimes, woodcutting, clearing, cropping and grazing by domestic and feral herbivores. The eradication of the dingo and provision of artificial watering points have probably also contributed to higher densities of kangaroos than were present before European settlement. These changes are likely to have had a significant impact on the amount and types of cover and food now available to bettongs reintroduced to LNP. It cannot be assumed that the habitat now available to the bettongs in LNP is the same as that present before they became extinct in the area. Therefore it is likely that habitat restoration, through the control of grazing pressure and the use of fire, is also essential for the survival of bettongs in LNP.

- **Recommendation 26:** Ensure that habitat quality, and its interaction with other factors such as predator activity, is considered when planning future reintroductions.

6.3 Recommended actions for the LNP bettong program

1. Future bettong reintroductions in LNP or similar habitats should not be undertaken in late autumn / early winter.
2. Large numbers of animals should be simultaneously released in future bettong reintroductions.
3. Future bettongs reintroductions need to incorporate a high level of integrated pest management before and after release events.
4. Continue monitoring of the trapping transects and opportunistic trapping throughout the park to establish patterns in bettong dispersal.
5. Use animals with some notion of predator awareness for future reintroductions.

6. Control foxes, cats and rabbits before bettong reintroduction and maintain low densities of these animals for the life of the program. Concentrate control efforts at times of release, increased predator or prey breeding, natural disturbances such as fire, and focus efforts on vegetation boundaries.
7. Allow native vegetation to regenerate by reducing grazing pressure by kangaroos and rabbits.
8. Conduct prescribed burns with the aim of increasing the suitability of habitat and availability of food for bettongs.
9. Continue to engage the Forensic Odontology Unit to identify cause of bettong death when predators are involved.
10. Use *Sir Track* whip collars for bettong monitoring in preference to the brass band loop collars.
11. Allocate time to trap some of the more difficult terrain of LNP, and actively search for bettong activity (tracks, scats and diggings).
12. Investigate the use of hair tubes for bettong detection and monitoring.
13. Conduct quarterly trapping of the Donington and Taylor's Landing trap transects if radio tracking is no longer used to monitor bettongs.
14. Use more than one stitch, if stitches are used to contain pouch young, or use the less disruptive trap return method of uniting young with female.
15. Collect bettong scats whenever possible and forward to Teresa Lebel, Melbourne Herbarium, for analysis.
16. Trial the use of oat bait trails in LNP to detect presence of bettongs, and/or survey opportunistically for bettongs if baiting rabbits.
17. Train staff to identify signs bettong activity and prepare a specific datasheet to encourage formal recording.
18. Involve students, volunteers and DEH staff from other districts in bettong monitoring and releases.
19. Keep accurate and up to date records of budgets, costs and labour effort.
20. Develop or adopt vegetation classification codes and provide staff with training in vegetation identification to ensure that more detailed habitat records are taken.
21. Continue to use quarterly 1080 baiting to control foxes. Use a variety of meat baits, and plan baiting around rainfall events if possible to increase uptake and extend bait life.
22. Conduct annual or biannual rabbit baiting of Donington Peninsula, in combination with warren mapping and blasting as needed.
23. Source funds to purchase explosives for warren destruction.
24. Keep accurate records of warren locations and details of timing and nature of control methods used.
25. Investigate the effectiveness of traps baited with lures to control cats.
26. Ensure that habitat quality, and its interaction with other factors such as predator activity, is considered when planning future reintroductions.
27. Perform additional translocations of bettongs to strengthen the established population and provide new genetic diversity.
28. Identify fungal assemblages before and after additional bettong reintroduction and establish monitoring sites.
29. Investigate opportunities for partnerships with industry. Examples include;
    - → Airline sponsorship, flights for students undertaking research on LNP bettongs.
    - → Inflight publicity of ecological restoration programs on the Eyre Peninsula.
    - → Sponsorship for supply of meat for fox baiting, oats for rabbit baiting, and explosives for rabbit warren destruction.

30. Identify opportunities for summer scholarships for University students to conduct research.
31. Develop partnerships with the Southern Eyre Integrated Pest Management program and the EP Natural Resource Management Board.
32. Identify and apply for grants to assist with program operation costs.
33. Continue to actively involve local communities.

7. Suggestions for future research studies

- Identify the influence of fox and cat moisture requirements on the effectiveness of baiting/trapping.
- Determine the significance of resource competition between bettongs and rabbits.
- Investigate bettong/predator interactions and the ability of bettong populations to cope with varying levels of predation.
- Assess the diversity of hypogeal fungi (truffles) in LNP by analysing bettong scats.
- Investigate the role of bettongs in fungal spore distribution
- Monitor the impact of introduced bettongs on their new environment.
- Determine the impacts of kangaroos, bettongs and rabbits grazing on orchids and foraging on fungi in LNP (Williams, S, *pers.comm*, 2004)
- Investigate interactions between vegetation recovery, kangaroos, bettongs and rabbits (Williams, S, *pers.comm*, 2004).
- Investigate the home range and diet of cats in VBCP and LNP.
- Investigate interactions between habitat quality and bettong survivorship.

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Appendix 1: Time line of significant events in the reintroduction program.

Date	Event
1997	Extensive fox baiting program began in LNP
12/1/99	Inspect Lincoln NP and select release sites
15/3/99	Initiate site preparation with extra fox baiting Establish small vertebrate survey sites (Mike young and local staff)
July / August 1999	Site preparation with extra fox baiting, spotlighting and flagging rabbit warrens (Mike Young and local staff)
26/9/99	Predator spotlighting (Mike Young and local staff)
September 1999	Contract ecologist Hafiz Stewart employed (Sept – Oct 99)
6/9/99	13 Bettongs relocated from VBCP to LNP
15/9/99	5 Bettongs relocated from VBCP to LNP
21/11/99	26 Bettongs relocated from VBCP to LNP
November 1999	Contract ecologist H Stewart finishes work and Bettong project officer Yoeri Mack employed (Oct 99 – Jan 00)
20- 27th October 1999	First trapping program to check condition of bettongs
2-6/12/99	Predator spotlighting and warren blasting (Mike Young)
7/12/99	Inititiate use of Sporting Shooters Association Australia, Hunting and Conservation Branch for predator spotlighting. Cat sighted on entrance road to LNP
8/12/99	Cat sighted on entrance road to LNP
15 –17/12/99	Kaz Harbst from SSAA shown spotlighting project
30/1/00	Bettong contractor, Yoeri Mack finishes work
12/2/00	Mike Young, Chris Holden flag warrens, general track survey and predator check
21-24th Feb 2000	Recollaring of radio collared bettongs
28-29th Feb 2000	Trapping to check fit of collars
April 2000	Bettong trapping transects lines established
21/3 & 22/3 March	Bettongs caught during small vertebrate survey
May 2000	Bettong trap transect line surveys undertaken
26-28th June 2000	Recollar of radio collared bettongs
5/7/00	First death recorded from radio tracked animal
6/7/00 – 3/8/00	Recollaring of radio collared bettongs
26/7/00	Bettong Project Officer, Lisa Pulman employed (26/7/00 – 20/10/00)
27/8/00	Mike Young and Regional Ecologist Nigel Cotsell discuss reintroduction project

Date	Event
25/9/00	Predator spotlight survey, Mike Young and local staff
4/10/00	Trapping transect undertaken, 1st LNP born bettong trapped on Donington transect
9/10/00	Recollaring of radio collared bettongs
12/10/00	3 bettongs found dead
20/10/00	Bettong contractor, Lisa Pulman finishes work
28/2/01	February 2001 Tulka fire, fire retardant dropped to stop spread into bettong population
	1 Bettong seen at Surfleet Point during fire fighting 53H 587729, 61495551
	1 Bettong seen on Taylors Landing road during fire fighting 53H 587700 6142687
26/3/01	March trap transect started, 3 new LNP bettongs caught Bettong Project Officer, Dave Cunningham employed (26/3/01 – 10/6/01)
30/3/01	29 bettongs relocated from VBCP to LNP
4/4/01	39 bettongs relocated from VBCP to LNP
April 2001	Radio track collars sent to Forensic Odontology unit via Mike Young and Peter Copley
26-30/4/01	Target fox bait, spotlight and prepare for warren blasting, Mike Young. Bettongs tracks absent from release area
5/5/01	5kg tabby cat caught near bettong release site
May 2001	Radio collars sent to Forensic Odontology unit
24/5/01	Donington bettong trapping grid undertaken
24/5/01	4kg tabby cat caught near September beach
Late May 2001	Rabbit warrens blasted in release area
10/6/01	Bettong contractor, Dave Cunningham finishes work
2-7/7/01 16-19/7/01	Intensive baiting, warren blasting, spotlighting, 1 bettong seen. Mike Young
July 01	Sporting shooters spend 1 week spotlighting and trapping for feral cats
6/8/01	AOE meeting, video conference discussion on bettong program.
4-7/9/01	Intensive baiting, blasting warrens, spotlighting
15/10/01	Bettong Project Officer, Dave Cunningham employed (15/10/01 – 27/6/02)
October 01	Recollaring of radio tracked bettongs
Dec 00 /. Jan. 01	Recollaring of radio tracked bettongs
January 2002	Bettong trapping transect undertaken
3/2/02	Free bait trail and spotlight of Donington Peninsula Two bettongs spotted
4/2/02	Spotlight of Donington Peninsula with bait trail 5 bettongs spotted
February / March 2002	Recollaring of radio collared bettongs
April 2002	Poison oat baiting for rabbits conducted on Donington Peninsula
27/6/02	Bettong Contractor Dave Cunningham finishes work

Date	Event
June 2002	Article on analysed Bettong collars published in Journal of Forensic Odonto-Stomatology
August / September 2002	Recollaring of radio collared bettongs Problems began with batch of collars not working / transmitting
February / March 2003	Recollaring of radio tracked bettongs
May 2003	Trapping transect undertaken
4/5/03	Bettong Contractor Ray Carpenter employed (4/5/03 – 17/8/03)
July / August 2003	Recollaring of radio tracked animals
September 2003	Radio collars sent to Forensic Odontology unit
5/11/03	Monitoring of animals ceased, trapping began to remove all collars remaining on animals
18/12/03	Flight over LNP to find remaining collared animals
Feb. 2004	Trapping transects undertaken
April 2004	Analysis of LNP bettong trapping and radio tracking began
May 2004	Non targeted trapping throughout upper Donington Peninsula 3 bettongs caught
July 2004	Donington trapping transect completed

Appendix 2: Analysis of bettong survivorship in Lincoln National Park 1999-2002.

By Steve Ball. July 2004

Summary: Radio-tracking data on the fate of 49 radio-collared adult brush-tailed bettongs (*Bettongia pencillata*) in the Donington Peninsula, Lincoln National Park, were used to estimate bettong survival probability on a three-monthly basis over three years from spring 1999 (initial release) to spring 2002. The population had very high survivorship in its first year, equivalent to an overall yearly survival probability of 0.91. However, in spring 2000, the three-monthly survival probability decreased to 0.61, and then to 0.76 in the 2000/01 summer (coincident with the nearby Tulka fire). In the year following the fire, three-month survival probabilities were 0.34 (autumn 2001), and then 0.48, 1.00 and 0.72.

The 22 radio-collared individuals present at the start of autumn 2001 (the three months of lowest survivorship following the Tulka fire) included eight bettongs still alive from the initial release (sourced from Venus Bay), six bettongs newly-released from Venus Bay, and six newly-released from St Peters Island. These three groups were analysed separately, and showed three-month survival probability estimates of 0.58, 0.30 and 0.01 respectively.

To determine sampling priorities for future monitoring of bettong populations, power analyses were undertaken to determine the size of confidence intervals around estimates of survivorship probability. This examined the importance of sample size (number of individuals = 5, 10, 20 or 40) and sampling frequency (confirming each bettong's status every 1, 7, 14 or 28 days). Randomly-generated data sets were simulated for two scenarios: three-month survival probability = 0.5 or 0.8. Analyses of these simulated data showed that it is far more important to increase sample size rather than sampling frequency.

Introduction: Radio-tracking of the bettong population in Lincoln National Park from spring 1999 till spring 2002 (still ongoing in 2004) has created a detailed record of dates when different individuals were known to be alive, and the timing of deaths. These data are clearly valuable for population management, both for real time insights and retrospective analyses into changes in survivorship.

Summary statistics and intuition provide some insight into bettong survivorship. For instance, if we start with 20 radio-collared individuals but six of these die within three months, we would estimate a three-month survival probability of 0.70 (i.e. 14/20). There are, however, some deficiencies in this treatment of survival data. Firstly, this approach ignores valuable information about the timing of deaths (e.g. imagine knowing that the six individuals died within 20 days of the start of the three-month period rather than within say, 70 days). Secondly, a data set may be too 'messy' for simple summary statistics. For example, we may start a three-month monitoring period with 20 individuals, but for some reason fail to radio-track three of these in the last two months, and fail to radio-track a further four in the last month. Dealing with censored data such as these is problematic for simple summary statistics.
Survival Analysis is a statistical procedure which models survival probability based on known time to death (relative to some specified starting time). This has the dual advantage of (a) making use of information about the timing of deaths, and (b) accommodating messy

data sets. Furthermore, Survival Analysis is based on the maximum likelihood technique, which enables confidence intervals to be calculated. The logic behind maximum likelihood estimation is to find the value of a variable (in this case a parameter describing survival probability) that has the greatest likelihood of having generated the observed data (Hilborn and Mangel, 1997).

This report is intended as a formal analysis of bettong survivorship in Lincoln NP using Survival Analysis. There are three main aims of this report:

1. Demonstrate how bettong survival probability changed over time;
2. Compare the survival probability of bettongs with different population histories (e.g. sourced from Venus Bay vs. St Peters Island);
3. Undertake power analyses to determine the relative importance of sample size (number of individuals) and sampling frequency (number of days between records of bettong status).

Methods: Bettong survival probability was modelled as a negative exponential function of time:

$$s(t) = e^{-\lambda t} \qquad \text{Eq. 1}$$

where s = survival probability, t = time (in days) and λ = the hazard rate

This equation is the simplest form of a set of possible survivor functions (Kleinbaum, 1996), whereby the probability of a still-living individual dying in the next time interval is constant over time (i.e. λ is fixed). Other, more complex survival functions allow this hazard rate to vary with time, e.g. according to the age of each individual. However, such models have more parameters and require large data sets for effective estimation. Because of the modest sample sizes of radio-collared bettongs in Lincoln NP, the simple model of constant hazard rate was chosen.

Importantly, bettong survival was modelled in this report as three-monthly 'snapshots' of survival probability. This means that although survival probability was treated as constant within a given three-month period, it is allowed to vary between these snapshots. Variation in survivorship due to the sex, age, release date and source population of individuals was ignored. However, for autumn 2001, sufficient data were available to compare the survival probability of bettongs recently sourced from St Peters Island and Venus Bay, as well as bettongs sourced from Venus Bay which had already been in Lincoln NP for one year.

Maximum likelihood estimation was used to estimate λ, the hazard rate, based on dated records of known bettong status. The raw data for each bettong were represented as a series of daytime radio-tracking observations, recorded as Same, New, Flushed or Dead. 'Same' refers to a bettong that was in the same nest site as its most recent known location, while 'New' refers to a bettong that was in a different nest site to its most recent known location (potentially a nest site it has been known to use earlier). 'Flushed' indicates that a bettong was disturbed from its nest site by the observer (intentionally or accidentally), and applies to both 'Same' or 'New' nest sites. 'Dead' means that the bettong was found dead or that a detached collar was found with predator chew marks. While flushing a bettong is irrefutable evidence that it is still alive, records of New nest sites were also treated as an indication that the bettong was still alive. Importantly, field staff described how new nest sites were investigated in such a way as to confirm bettong status. When approaching what appeared to be a new location for a bettong, the site was carefully circled to triangulate its location using the radio-tracking receiver. If this pointed convincingly toward a potential nest site (e.g. suitable collection of grass, sticks and leaf litter), the site was recorded as New. If there was sufficient uncertainty about the presence of a suitable nest site, the area was approached until either (a) a suitable site was found, (b) the bettong was flushed, or (c) the bettong was found dead. Although it is possible that a bettong was dead but hidden in what appeared to be a suitable nest site (i.e. mistakenly recorded as New), this scenario is considered unlikely, with the high majority of bettong deaths leaving the body away from nest sites. Instances of Same nest sites were excluded from further analysis, since they were generally not investigated with sufficient scrutiny to confirm bettong status.

Data from a total of 49 bettongs were available for spring 1999 till spring 2002. However, for any given three-month period, the sample of bettongs was much smaller that this total (median = 12; max = 22; min = 2). To a large extent these smaller sample sizes reflect the timing of bettong releases and deaths. However there were also instances when radio-collared bettongs were temporarily excluded from analysis if they had not been radio-tracked during that period. For each three-month period, data were summarised into a list of (a) bettongs still alive at their last record for that period, and (b) bettongs that had died during the three months.

For a still-living bettong, the statistical likelihood was calculated as:

$$s(t) = e^{-\lambda t} \qquad \text{(Eq. 1)}$$

where t = the number of days from the start of the three-month period until the date the bettong was last confirmed as alive.

For a bettong death, the likelihood was calculated as:

$$s(t) = e^{-\lambda t^*} - e^{-\lambda t} \qquad \text{Eq. 2}$$

where t = the number of days from the start of the three-month period until the date the bettong was found dead, and t* = the number of days from the start of the period until the date the bettong was last confirmed as alive. Equation 2 accounts for uncertainty about when the bettong actually died, since all we know is that the bettong died some time between t* and t.

Note that for bettongs released/collared after the start of a three-month period, data were calculated relative to the date of collaring (rather than the number of days since the start of the three-month period).

The likelihood (adapted from Marubini and Valsecchi,1995) for a given value for λ was then the joint probability across all bettongs in the three-month sample, as:

$$\text{Likelihood} = \prod_{i=1}^{n} \left(e^{-\lambda.t}\right)^{y} \left(e^{-\lambda.t^*} - e^{-\lambda.t}\right)^{y-1} \qquad \text{Eq. 3}$$

where y = 1 for a bettong whose last record confirmed it to be alive; y = 0 for a bettong that died during the three-month period; n = the number of bettongs in a given three-month sample, and i denotes each bettong.

The likelihood of alternate values for λ was calculated in an Excel spreadsheet, and the value of λ which maximised this likelihood was treated as the 'best', or maximum likelihood estimate of this parameter (λ_{mle}). The 95% confidence interval around λ_{mle} was then calculated as the two values of λ with a negative log likelihood 1.92 units in excess of the minimum negative log likelihood (Hilborn and Mangel, 1997). These values for λ were then expressed as a three-month survival probabilities using:

$$s(t) = e^{-\lambda t} \qquad \text{(Eq. 1)}$$

where t = 90, 91 or 92 days, depending on the season.

Results:

Changes in bettong survivorship over time

The first year of monitoring was characterised by very high bettong survivorship (Figure 1), with only one death among radio-collared individuals in the first 12 months following initial release into the Park (Table 1), and an overall yearly survival probability of 0.91.

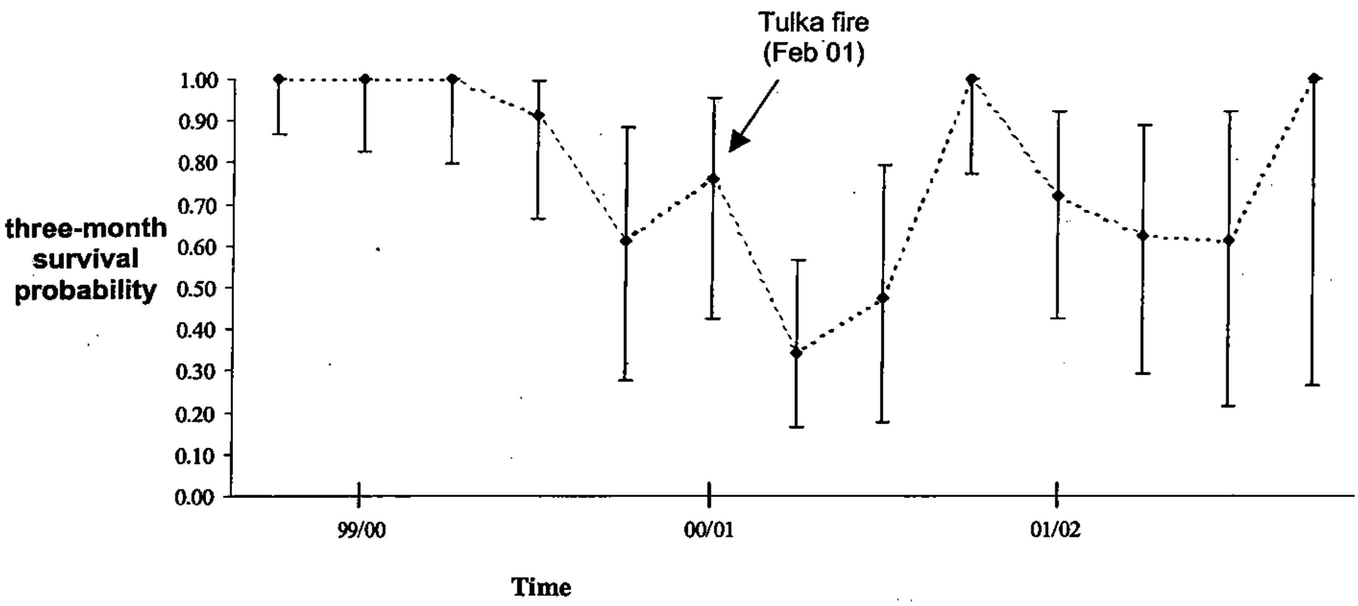

Figure 1. Changes in three-monthly survival probability of bettongs over the study period (maximum likelihood estimate ± 95% confidence interval). Upper confidence limits are bounded at 1.00. The timing of the Tulka fire (Febuary 2001) is indicated.

Starting in spring 2000, the survival probability of bettongs began to decline, with a three-month survival probability of 0.61. Notably, this was prior to the nearby Tulka fire, and two of the three deaths were attributed to predation (the first instances of predation recorded among radio-collared bettongs in the Park). In the 2000/01 summer (coincident with the Tulka fire in late February), survival probability was 0.76. This was then followed in autumn 2001 by the lowest survivorship of the entire study period, with a three-month survival probability of only 0.34. Importantly, this three-month period began with two additional releases of individuals into the Park: six radio-collared bettongs from

Venus Bay and six from St Peters Island. Survivorship was particularly low among these newly-released bettongs, and this may have biased the estimated survivorship to some extent (see below for detailed comparison of survivorship of these bettongs). Survivorship remained generally low for the rest of the study period, except for two three-month periods without mortality (survival probability = 1.00). While overall yearly (spring-to-winter) survival probability was 0.91 for the first year, it was only 0.08 in the second year, and 0.27 in the third year (calculated by simply multiplying the four three-monthly probabilities for a given year).

Survivorship of bettongs in autumn 2001: a comparison based on population history.

The sample of 22 radio-collared bettongs monitored in autumn 2001 comprised the following groups: eight bettongs still alive from the original release in spring 1999 (sourced from Venus Bay NP), six bettongs released from Venus Bay NP on 30/3/01, six bettongs released from St Peters Island on 4/4/01, an additional bettong from Venus Bay NP released on 24/5/01 and an *in situ* recruit from Lincoln NP collared on 24/5/01. All except the last two bettongs were used to compare the following categories of survivorship:

(1) autumn 2001 survivorship of the eight bettongs remaining from the spring 1999 release from Venus Bay
(2) autumn 2001 survivorship of the six newly-released bettongs from Venus Bay
(3) autumn 2001 survivorship of the six newly-released bettongs from St Peters Island

In addition, survival probability was characterised for:

(4) spring 1999 survivorship of the 22 bettongs originally released from Venus Bay (includes the eight individuals remaining in 2001)

It should be noted that this analysis was conducted *post hoc* in the knowledge that bettongs sourced from St Peters Island had unusually low survivorship (three of the six bettongs were found dead within a week of release).

This comparison of survival probability was undertaken as a Bayesian analysis. Bayesian statistics uses the likelihood principle, and assigns a probability or "weighting" to the different values of a parameter. For bettong survivorship, the parameter of interest is itself a probability (three-month survival probability). With a large data set, Bayesian analysis would assign heavy weighting to a particular estimate of survival probability; while a small data set would lead to a low weighting spread over a wide range of possible survival probabilities.

Table 1. Summary of three-month survivorship data for each of 49 radio-collared bettongs. Values with brackets indicate bettong deaths; e.g. 87(60) indicates that bettong #2 was found dead 87 days into autumn 2001, and was previously confirmed alive 60 days into that three-month period. Single values without brackets indicate bettongs alive at last confirmation of status; e.g. a value 79 for bettong #2 indicates this bettong's status was last confirmed 79 days into spring 1999, when it was found to still be alive. For bettongs released/collared after the start of a three-month period, data were calculated relative to the date of collaring. Individuals sourced from St Peters Island are denoted "*"; recruits from Lincoln NP "†"; and individuals from Venus Bay are without a symbol. Bettong sex is indicated as F or M. Deaths due to predation are indicated (if blank, the bettong did not die or cause of death was not determined, e.g. possibly old age).

Bettong ID num.	Spring 99	Summer 99/00	Autumn 00	Winter 00	Spring 00	Summer 00/01	Autumn 01	Winter 01	Spring 01	Summer 01/02	Autumn 02	Winter 02	Spring 02	Predation?
1 (F)	79	35	77	70	84	89	88	54	89	90	67	81		
2 (F)	80	82	2	90	49	89	87(60)							
3 (F)	80	7	63	90	49	89	91(84)							
4 (F)	70	82		25										Yes
5 (F)	78	71	43	90	46	89(39)								
6 (F)	44						90	74	89	89	67(38)			
7 (F)	79	72	44											
8 (F)	80	85												
9 (F)	70	70	89	16										
10 (F)	79	70	89	65(47)										
11 (F)	78	21	63	69	46	89	84	74(54)						
12 (F)	79	68	44											
13 (F)	79	82	76	87	46	89	77(67)							Yes
14 (F)	69	83	1		46	89	92	74	89	85	69	79	60	
15 (F)	35													
16 (M)	36						90(88)							Yes
17 (M)	51			37										
19 (M)	42													
22 (M)	4	21	2	89										
23 (M)	9	70	2	89	71(27)									
25 (M)	9		89	89	71(63)									Yes
26 (M)	4													
27 (F)			85	89	71(63)									Yes
28 (F)					4	89(39)								Yes
30 (M)							61	67(60)						
31 (F)							1(0)							
32 (F)							33(31)							Yes
33 (F)							50(41)							Yes
34 (F)							24							
35* (F)							5(2)							Yes
36* (F)							58(48)							
37* (F)							48(23)							
38* (F)							7(5)							Yes
39* (F)							5(1)							
40* (M)							5							
41 (M)							63	72(38)						Yes
42 (M)							6	30(6)						Yes
43† (M)							8	89	79	89	69	87(32)		Yes
44† (F)									25					
45 (M)									57	81(68)				
46 (F)									56	61(47)				Yes
47 (F)									27					
48 (M)									55	89	69(48)			Yes
49 (F)									55	89	35			
50† (F)									31	90	69	87(51)		Yes
51† (F)									29	49(41)				
52 (F)										22	57(28)			Yes
53 (M)										9	69	82	72	
54† (F)										3	48			
Total bettongs	22	15	15	14	11	8	22	8	12	13	10	5	2	
Survival probability	1.00	1.00	1.00	0.91	0.61	0.76	0.34	0.48	1.00	0.72	0.62	0.61	1.00	

Bayesian statistics requires that the user initially specify "prior probabilities" (initial weightings) for the different values of the parameter(s) being estimated. In the absence of other information, uniform prior probabilities are assumed, giving equal weighting to each value of the parameter. Accordingly, the three-month survival probability of bettongs was represented as a range of hypothetical values from 0 to 1 in steps of 0.001, with each of these values assigned equal prior probability of being the true survival probability. The essence of Bayesian statistics is to then combine these prior probabilities with the likelihood of the observed data (i.e. the survival data in Table 1) and thereby calculate "posterior probabilities" – i.e. our final weighting for each value of the parameter.

Figure 2 shows the posterior distributions for each of the four data sets.

While the three-month survival probability for all 22 bettongs in autumn 2001 was estimated at 0.34 (Figure 1; Table 1), survival probability varied within the population as follows:

(1) 0.58 (autumn 2001; Venus Bay 1999 release)
(2) 0.30 (autumn 2001; Venus Bay 2001 release)
(3) 0.01 (autumn 2001; St Peters Island 2001 release)

This contrasts with the high survivorship of bettongs at the start of the study period:

(4) 1.00 (spring 1999; Venus Bay 199 release)

The posterior probability distributions in Figure 2 can be compared by multiplying the values of one data set with those of another. This provides an estimate of the probability that survival probability was higher for one set of bettongs than for another set. For example, there is estimated to be a 0.08 probability that survival probability in St Peters Island bettongs was higher than in Venus Bay (1999-released) bettongs in autumn 2001 (i.e. 0.92 probability that it was lower). In general there was very strong separation in survival probability among the bettong samples of Figure 2 (see Table 2). NB: a probability of 0.50 would indicate very weak separation between two distributions.

Power analysis for estimating survival probability: sample size versus sampling frequency.

Power analyses for estimating survival probability were conducted with 10 replicates per scenario to demonstrate variation in the location and size of 95% confidence intervals.

Sampling frequency had very little effect on estimates of survival probability. That is, a comparison of survival probability estimates based on data collected once every 1, 7, 14, and 28 days showed very little difference in the size of 95% confidence intervals or the dispersion of maximum likelihood estimates (Figures 3 and 4). This applies to all scenarios of sample size (5, 10, 20 and 40 bettongs), and survival probability (0.5 and 0.8) examined.

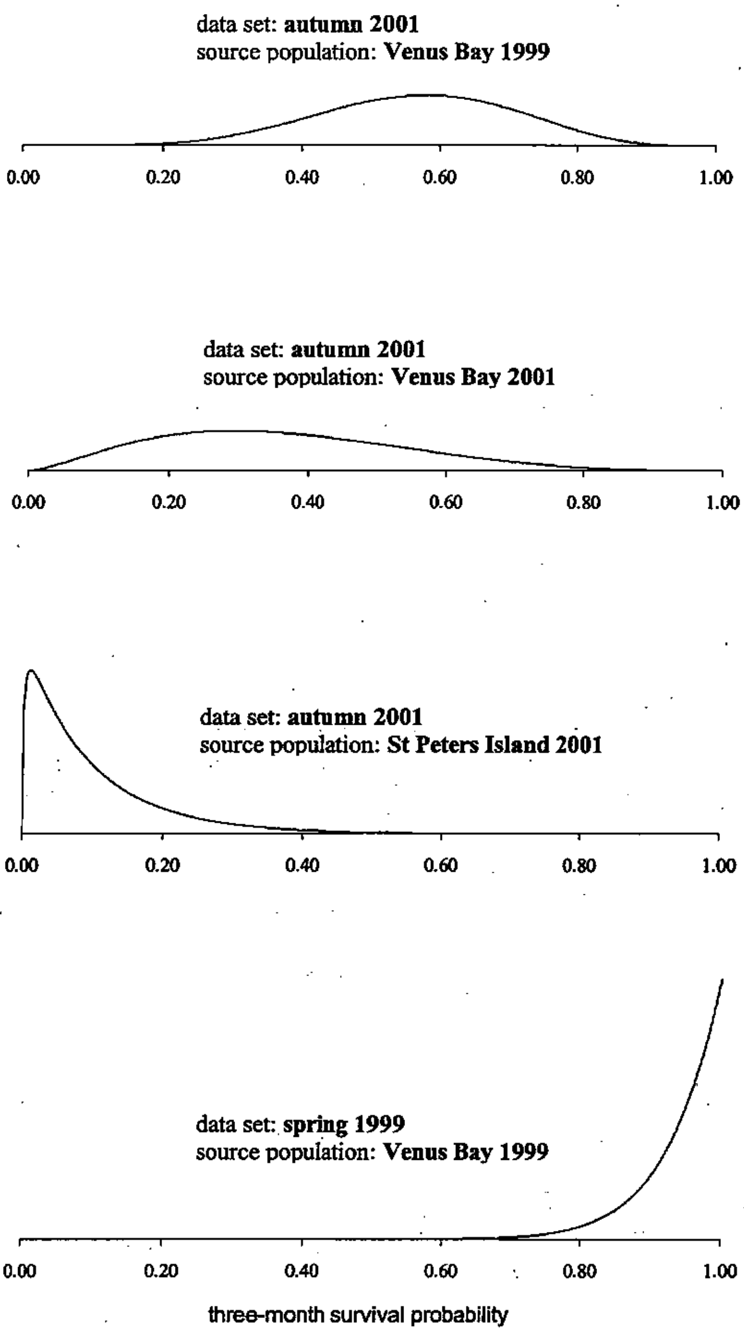

Figure 2. Bayesian analysis of bettong survivorship. Shown are the posterior probability distributions describing three-month survival probability for four different data sets. Y-axis units are equivalent to the probability density or "weighting" for each value on the x-axis (scaled so that the area under each curve sums to 1). The maximum likelihood estimate for each data set is at the peak probability density (0.58, 0.30, 0.01 and 1.00 respectively).

Table 2 Matrix showing the probability that each of four survival probabilities of Figure 2 was larger than each of the other survival probabilities. Each value refers to the probability that a given column entry was greater than the corresponding row entry. For example, there was a 0.08 probability that survival probability in St Peters Island bettongs was higher than in Venus Bay (1999-released) bettongs in autumn 2001 (i.e. 0.92 probability that it was lower).

	Autumn 2001 Venus Bay 99	Autumn 2001 Venus Bay 01	Autumn 2001 St Peters Is. 01	Spring 99 Venus Bay 99
Autumn 2001 Venus Bay 99	NA	0.19	0.01	0.92
Autumn 2001 Venus Bay 01	0.81	NA	0.08	0.93
Autumn 2001 St Peters Is. 01	0.99	0.92	NA	0.94
Spring 99 Venus Bay 99	0.08	0.07	0.06	NA

In contrast, sample size (number of bettongs in each three-month sample) had a marked effect on the quality of survival probability estimates, with the size of confidence intervals decreasing consistently (and the location of maximum likelihood estimates more closely matching the true, simulated value) as sample size increased. This applies to both levels of survival probability examined.

Based on these results, it is suggested that sample size should be a higher priority than sampling frequency for future monitoring of survivorship. For the purpose of estimating three-monthly survival probability, it is sufficient to confirm a bettong's status (alive or dead) every 14 to 28 days. Note that this ignores instances when bettong status is recorded as Same (i.e. the bettong is in the same nest site as the previous record), as this is not an indication of bettong status. Whenever possible, a minimum of 10 (ideally 20) bettongs should be monitored to confidently indicate changes in bettong survivorship. However if survivorship estimates are required over smaller time intervals (e.g. monthly) or with more confidence, sample frequency and sample size should be increased accordingly.

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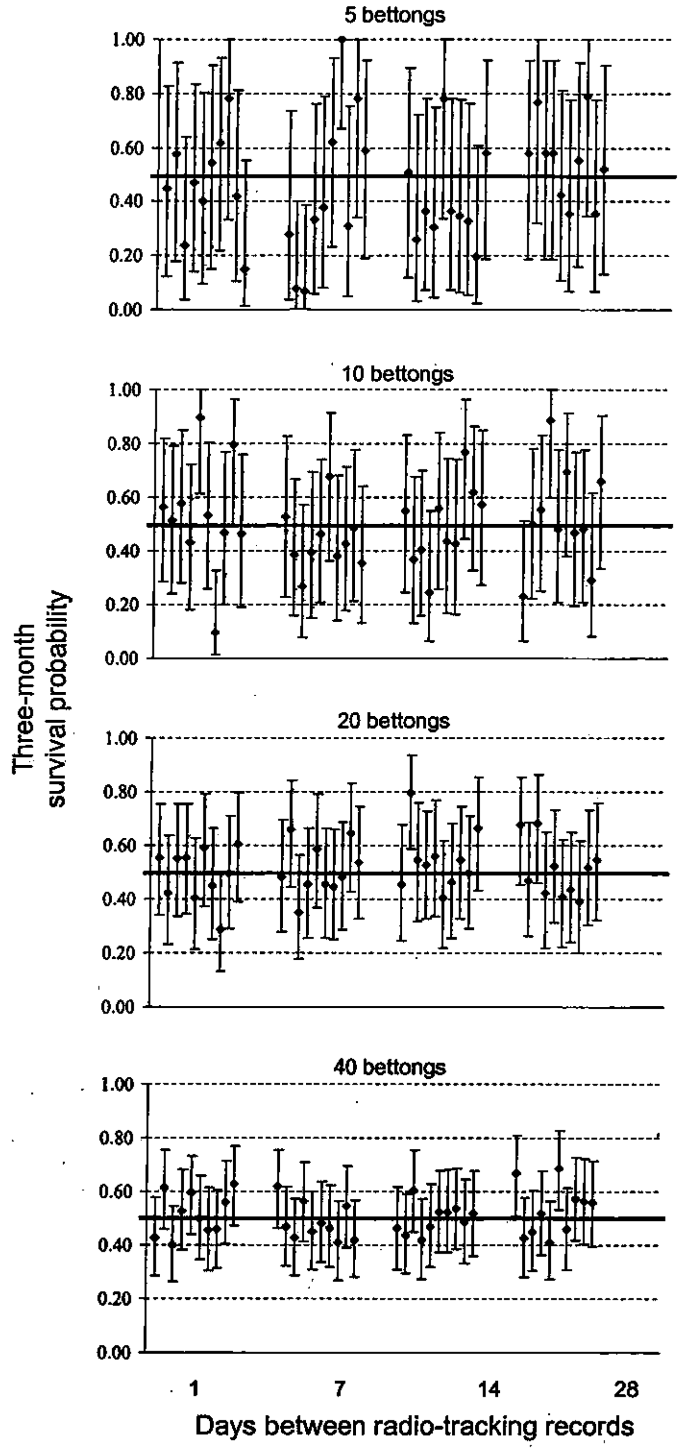

Figure 3. Power analysis for estimates of three-month bettong survival probability when true (simulated) probability = 0.5. Sample size varies (top to bottom) as 5, 10, 20 or 40 bettongs. Sampling frequency varies (across each graph) with bettong status (alive or dead) being confirmed once every 1, 7, 14 or 28 days. For each combination of sample size and frequency there are 10 replicates (based on randomly-generated data), each showing the maximum likelihood estimate (dot) and 95% confidence interval. Some confidence intervals are truncated at survival probabilities of 0 or 1.

Appendix 3: Summary costs for LNP Bettong program, excluding contractor and staff wages

Date	Item	Supplier	Cost
Trapping			
Set-up equipment for trapping			
1999	trap bag		$15
1999	trap tool box x 2	Harris scarf	$20
1999	2kg spring scale for trapping		$35
1999	plastic tub x 1 for storing collaring equip.	Woolworths	$14
1999	Caliper ruler	State supply	$15
8/09/1999	40 cage traps	Sheffield wire products	$1335
7/02/2000	200 tar dipped droppers	Lincoln Rural supplies	$725.25
7/02/2000	Steel tags for trap transect droppers	Lincoln Steel Supplies	$300
17/09/1999	antennae for tracker	Roes Electrical	$47.7
		Total	**$2,507**
Bait costs			
1999	Bait for trapping	Coles / Woolworths	$9
2000	Bait for trapping	Coles / Woolworths	$81
2001	Bait for trapping	Coles / Woolworths	$72
2002	Bait for trapping	Coles / Woolworths	$90
2003	Bait for trapping	Coles / Woolworths	$90
2004	Bait for trapping	Coles / Woolworths	$9
		Total	**$351**
		Total trapping costs	**$2,858**
Collaring / monitoring			
Set-up equipment for collaring / monitoring			
1999	Lock-tite for collar nuts	Lincoln auto electrical	$12
1999	2 x Calex cable 1 metre	Fleet electrical	$47.70
1999	GPS, Garmin 12	Electric bug	$500
1999	screw driver for small nuts	Home Timber and Hardware	$24
1999	Flight for Jason van Weenan to assist in collaring of 1st release animals	Kendall Airlines	$300
1999	Handheld radio receiver rx5 x 2	Biotelemetry	$1,500
1999	3 element Yargi antennae for tracking x 2	Biotelemetry	$472
1999	Radio track head phones x 1	Biotelemetry	$25
1999	Pocket knife	Home Timber and Hardware	$15
1999	Plastic tub x 1 for storing monitoring equipment	Woolworths	$20
2001	Battery recharger	State supply	$60
2001	2 pack of 4 rechargeable batteries	State supply	$35
2003	Lock-tite for collar nuts	Lincoln auto electrical	$24
		Total	**$3,035**
On-going monitoring			
2002	Flight for check of missing bettongs	Malcolm Cat plane charter	$150
1999	Batteries for tracking pack 12 x 4, non-recharge	Coles / Woolworths	$60
2000	Batteries for tracking pack 12 x 4, non-recharge	Coles / Woolworths	$60
2001	Batteries for tracking pack 12 x 4, non-recharge	Coles / Woolworths	$60
2002	Batteries for tracking pack 12 x 4, non-recharge	Coles / Woolworths	$60
2003	Batteries for tracking pack 12 x 4, non-recharge	Coles / Woolworths	$60
2004	Batteries for tracking pack 12 x 4, non-recharge	Coles / Woolworths	$30
		Total	**$480**
		Total	**$351**
		Total trapping costs	**$2,858**
Date	**Item**	**Supplier**	**Cost**

Collars			
1999	35 mortality switch TX LDL-M collars @ $120	Biotelemetry	$4200
9/08/2000	change existing collars to non-mortality switch collars	Biotelemetry	$528
24/02/2001	7 non-mortality switch collars @ $130	Biotelemetry	$1071
2/03/2001	7 non-mortality switch collars	Biotelemetry	$1056
9/03/2001	supply 1 collar	Biotelemetry	$44
26/03/2001	17 collars supplied	Biotelemetry	$748
27/03/2001	supply 1 collar	Biotelemetry	$44
30/07/2001	Battery replacement (7 collars)	Biotelemetry	$886
8/08/2001	Battery replacement (20 collars)	Biotelemetry	$880
22/10/2001	Battery replacement	Biotelemetry	$805.45
27/02/2002	Battery replacement (11 collars), one new collar supplied	Biotelemetry	$507.5
3/12/2002	Battery replacement (15 collars)	Biotelemetry	$600
20/05/2003	4 collars in place of suspect collars that had batteries replaced	Biotelemetry	no cost
14/07/2003	6 microlite radio transmitter with loop collars	Titley Electronics	$1534.5
		Total for collars	**$12,904**
		Total for collaring / monitoring	**$29,324**
Threat abatement (directed to bettong program - other general park threat abatement not listed)			
Rabbit control			
3/10/2001	Explosives	UEE Explosives Australia	$771
1/02/2002	Quad bike and bait layer hire	Southern Eyre Animal Control Board	$426.85
1/02/2002	Oats for rabbit baiting	Southern Eyre Animal Control Board	$40
		Total rabbit control	**$1237.85**
Fox control			
12/05/2003	buckets for bait	Leader distributors	$45.53
7/05/2003	kangaroo meat	Whites meats	$240
		Total fox control	**$285.53**
Cat control			
13/06/2003	Eco trap x 2	Eco trap pty ltd	$817
2001	Birdy tweeters x 6 @ $12	Dick Smith Electronics	$72
2002	Phonic Auditary Devices x 4 @ 435	CALM, WA	$140
1999	Leg hold traps x 15		$225
2000 - 2004	$3 liver on 10 occassions for bait	Coles butchers	$30
		Total cat control	**$1284**
		Total threat abatement	**$4330.78**
		Total with threat abatement	**$36,512**
		Total excluding threat abatement	**$32,182**

Appendix 4: Summary of staff/ contractor/ volunteer involvement in program

4 A: Staff bettong monitoring and collaring expenses

Staff involvement		Labour expenses				Vehicle expenses		
Date	**Activity**	**staff hrs**	**Staff involved**	**Rate**	**Total**	**km**	**Fuel**	**Total $ veh**
1998/1999								
12/01/1999	Release site selection	28	JvW, SW, PC, MY	20	560	120	0.47	56.4
1999/2000								
22/07/1999	Preparation release area	7.5	MY	19	142.5	90	0.47	42.3
23/07/1999	Preparation release area	7.5	MY	19	142.5	90	0.47	42.3
24/07/1999	Preparation release area	7.5	MY	19	142.5	90	0.47	42.3
25/07/1999	Preparation release area	7.5	MY	19	142.5	90	0.47	42.3
5/08/1999	Preparation release area	7.5	MY	19	142.5	90	0.47	42.3
6/09/1999	Preparation release area	7.5	MY	19	142.5	90	0.47	42.3
7/09/1999	Preparation release area	7.5	MY	19	142.5	90	0.47	42.3
8/09/1999	Preparation release area	7.5	MY	19	142.5	90	0.47	42.3
9/09/1999	Preparation release area	7.5	MY	19	142.5	90	0.47	42.3
17/08/1999	Preparation release area	7.5	MY	19	142.5	90	0.47	42.3
19/08/1999	Preparation release area	7.5	MY	19	142.5	90	0.47	42.3
20/08/1999	Preparation release area	7.5	MY	19	142.5	90	0.47	42.3
Aug-99	Site preparation	60	MY	19	1140	90	0.47	42.3
5/09/1999	Tracking	20	JSt, JVW	19	380	90	0.47	42.3
8/09/1999	Tracking	7.5	JT	19	142.5	90	0.47	42.3
9/09/1999	Tracking	7.5	TB	17	127.5	90	0.47	42.3
10/09/1999	Tracking	7.5	TB	17	127.5	90	0.47	42.3
12/09/1999	Tracking	7.5	TB	17	127.5	90	0.47	42.3
14/09/1999	Tracking	7.5	TB	17	127.5	90	0.47	42.3
14/09/1999	Trap VBCP for translocation	30	BR, BD, TB	20	600	550	0.47	258.5
15/09/1999	Tracking	7.5	TB	17	127.5	90	0.47	42.3
20/09/1999	Tracking	7.5	TB	17	127.5	90	0.47	42.3
21/09/1999	Tracking	7.5	TB	17	127.5	90	0.47	42.3

Date	Activity	staff hrs	Staff involved	Rate	Total	km	Fuel	Total $ veh
22/09/1999	Tracking	7.5	TB	17	127.5	90	0.47	42.3
23/09/1999	Tracking	7.5	JT	20	150	90	0.47	42.3
25/09/1999	Tracking	7.5	JT	20	150	90	0.47	42.3
26/09/1999	Tracking	7.5	TB	17	127.5	90	0.47	42.3
26/09/1999	Spotlighting	7.5	MY	20	150	120	0.47	56.4
27/09/1999	Tracking	7.5	TB	17	127.5	90	0.47	42.3
30/09/1999	Tracking	7.5	MF	17	127.5	90	0.47	42.3
1/10/1999	Tracking	10	GG, JD	17	170	90	0.47	42.3
6/10/1999	Tracking	10	GG, JD	17	170	90	0.47	42.3
7/10/1999	Tracking	5	DW	20	100	90	0.47	42.3
8/10/1999	Tracking	5	DW	20	100	90	0.47	42.3
13/10/1999	Tracking	10	JD, GG	17	170	90	0.47	42.3
20/10/1999	Tracking	15	JD, GG	17	255	90	0.47	42.3
21/10/1999	Tracking	15	GG, JD	17	255	90	0.47	42.3
26/10/1999	Tracking / trapping	6	TB	17	102	150	0.47	70.5
27/10/1999	Trapping	7.5	TB	17	127.5	150	0.47	70.5
2/12/1999	Spotlight/ warren bait	7.5	MY	19	142.5	90	0.47	42.3
3/02/1999	Spotlight/ warren bait	7.5	MY	19	142.5	120	0.47	56.4
4/12/1999	Spotlight/ warren bait	7.5	MY	19	142.5	120	0.47	56.4
5/12/1999	Spotlight/ warren bait	7.5	MY	19	142.5	120	0.47	56.4
7/12/1999	Sporting shooters meeting	5	MY	19	95		0.47	
9/01/2000	Tracking	6	SM	17	102	90	0.47	42.3
Feb-00	Preparing trap transect	60	SM, GG, JS, JD	17	1020	300	0.47	141
7/02/2000	Trapping	5	MF	18	90	90	0.47	42.3
9/02/2000	Trapping	3	MF	18	54	90	0.47	42.3
10/02/2000	Tracking	12	JS, JD, MN	17	204	90	0.47	42.3
14/02/2000	Tracking	3	MF	18	54	90	0.47	42.3
14/02/2000	Check release area	4	MY, CH	19	76	100	0.47	47
21/02/2000	Trapping	15	MF, SM	18	270	90	0.47	42.3
21/02/2000	Tracking	4	MF	17	68	90	0.47	42.3
22/02/2000	LNP trapping, collar	22.5	MF, JVW, SM	18	405	150	0.47	70.5
23/02/2000	LNP trapping, collar	22.5	MF, JVW, SM	18	405	150	0.47	70.5
24/02/2000	Trapping	3	MF	18	54	90	0.47	42.3

Date	Activity	staff hrs	Staff involved	Rate	Total	km	Fuel	Total $ veh
28/02/2000	LNP trapping, collar	22.5	MF, JVW, SM	18	405	150	0.47	70.5
29/02/2000	LNP trapping, collar	22.5	MF, JVW, SM	18	405	150	0.47	70.5
2/03/2000	Tracking	4	MF	18	72	90	0.47	42.3
3-Mar	Tracking	4	MF	18	72	100	0.47	47
6/03/2000	AoE meeting	5	RA, DA, PC, DH, JS, JVW, MY, JT, SM	20	100		0.47	0
3/04/2000	Trapping	10	MF, SM	18	180	100	0.47	47
4/04/2000	Trapping	10	MF, SM	18	180	100	0.47	47
5/04/2000	Trapping	5	MF	18	90	100	0.47	47
13/04/2000	Trapping	7.5	MF	18	135	100	0.47	47
14/04/2000	Trapping	7.5	MF	18	135	100	0.47	47
1/04/2000	School group Bettong talk	10	SM, DH	19	190	90	0.47	42.3
3/05/2000	Tracking	4	SM	16	64	90	0.47	42.3
16/05/2000	Tracking	4	SM	16	64	90	0.47	42.3
17/05/2000	Tracking	3	SM	16	48	90	0.47	42.3
29/05/2000	Tracking	4	SM	16	64	90	0.47	42.3
30/05/2000	Tracking	2	SM	16	32	90	0.47	42.3
5/06/2000	Tracking	7	SM	16	112	90	0.47	42.3
17/06/2000	Tracking	4	SM	16	64	90	0.47	42.3
20/06/2000	Tracking	10	NC, MF	16	160	100	0.47	47
26/06/2000	Trapping	15	MF, SM	17	255	100	0.47	47
27/06/2000	Trapping	15	MF, SM	17	255	100	0.47	47
28/06/2000	Trapping	15	MF, SM	17	255	100	0.47	47
2000/2001								
6/07/2000	Trapping	15	MF, JT	20	300	100	0.47	47
7/07/2000	Trapping	7.5	MF	18	135	90	0.47	42.3
8/07/2000	Trapping	7.5	MF	18	135	90	0.47	42.3
9/07/2000	Trapping	5	MF	18	90	90	0.47	42.3
2/08/2000	Trapping	15	SM, MF	18	270	90	0.47	42.3
3/08/2000	Trapping	10	SM, MF	18	180	90	0.47	42.3
27/08/2000	Project mtg / site visit	15	MY, NC	19	285	90	0.47	42.3
11/09/2000	AoE meeting	5	DA, NC, PC, SW, JT, JVW, MF, TG,	20	100		0.47	0

			SM, RA					
Date	**Activity**	**staff hrs**	**Staff involved**	**Rate**	**Total**	**km**	**Fuel**	**Total $ veh**
25/09/2000	Spotlight release area	5	MY	19	95	120	0.47	56.4
4/10/2000	Tracking	5	MF	18	90	100	0.47	47
5/10/2000	Tracking	5	SM	16	80	90	0.47	42.3
6/10/2000	Tracking	5	SM	16	80	90	0.47	42.3
9/10/2000	Trapping	7.5	MF	18	135	90	0.47	42.3
10/10/2000	Trapping	7.5	MF	18	135	90	0.47	42.3
11/10/2000	Trapping	7.5	MF	18	135	90	0.47	42.3
12/10/2000	Trapping	15	MF, NC	21	315	90	0.47	42.3
13/10/2000	Trapping	15	MF, TG	20	300	90	0.47	42.3
14/10/2000	Tracking	5	MF	18	90	90	0.47	42.3
7/11/2000	Tracking / trapping	10	MF, SM	18	180	90	0.47	42.3
8/11/2000	Trapping	15	MF, SM	18	270	90	0.47	42.3
9/11/2000	Trapping	10	MF, SM	18	180	90	0.47	42.3
24/11/2000	Tracking	5	MF	18	90	90	0.47	42.3
4/12/2000	Trapping	5	MF	18	90	90	0.47	42.3
5/12/2000	Trapping	15	MF, JB	13	195	90	0.47	42.3
8/12/2000	AoE meeting	5	SW, JS, MF, JVW, JT, TG, NC, DA, SM	20	100			
18/01/2001	Tracking / trapping	8	MF	18	144	90	0.47	42.3
19/01/2001	Tracking/ trapping	5	MF	18	90	90	0.47	42.3
3/02/2002	Bait trail set up	5	JT	20	100	120	0.47	56.4
3/02/2002	Bait trail spotlight	9	SM, JT, DF	20	180	120	0.47	56.4
4/02/2002	Bait trail spotlight	9	DA, NC, AF	20	180	120	0.47	56.4
22/02/2001	Tracking	7.5	MF	18	135	90	0.47	42.3
23/02/2001	Tracking	7.5	MF	18	135	90	0.47	42.3
24/02/2001	Tracking	7.5	MF	18	135	90	0.47	42.3
25/02/2001	Tracking	7.5	MF	18	135	90	0.47	42.3
28/02/2001	Tracking	6	MF	18	108	90	0.47	42.3
2/03/2001	Tracking	4	MF	18	72	90	0.47	42.3
3/03/2001	Tracking	36	MF, DA, BD, GJ	19	684	180	0.47	84.6
26/03/2001	Trapping	7.5	MF	18	135	90	0.47	42.3
27/03/2001	Trapping	7.5	MF	18	135	90	0.47	42.3
29/03/2001	Trapping	22.5	MF, SB, JS	18	405	90	0.47	42.3

Date	Activity	staff hrs	Staff involved	Rate	Total	km	Fuel	Total $ veh
14/04/2001	Mtg re: LNP bettong project	2	MY, PC	20	40		0.47	0
16/04/2001	Mtg re: LNP bettong project	2	MY, SW	20	40		0.47	0
1/04/2001	Tracking	5	MF	18	90	90	0.47	42.3
26/04/2001	Target bait, prep warren blast and spotlight	7.5	MY	19	142.5	120	0.47	56.4
27/04/2001	Target bait, prep warren blast and spotlight	7.5	MY	19	142.5	120	0.47	56.4
28/04/2001	Target bait, prep warren blast and spotlight	7.5	MY	19	142.5	120	0.47	56.4
29/04/2001	Target bait, prep warren blast and spotlight	7.5	MY	19	142.5	120	0.47	56.4
30/04/2001	Target bait, prep warren blast and spotlight	7.5	MY	19	142.5	120	0.47	56.4
24/05/2001	Trapping	7.5	MF	18	135	90	0.47	42.3
25/05/2001	Trapping	7.5	MF	18	135	90	0.47	42.3
26/05/2001	Trapping	7.5	MF	18	135	90	0.47	
20/06/2001	Discuss re: LNP bettong issues	3	MY, DA. DAr	19	57			
23/06/2001	Tracking	4	MF	18	72	120	0.47	56.4
2001/2002								
2/07/2001	Intensive baiting, blast warrens, spotlight	7.5	MY	19	142.5	120	0.47	56.4
3/07/2001	Intensive baiting, blast warrens, spotlight	7.5	MY	19	142.5	120	0.47	56.4
4/07/2001	Intensive baiting, blast warrens, spotlight	7.5	MY	19	142.5	120	0.47	56.4
5/07/2001	Intensive baiting, blast warrens, spotlight	7.5	MY	19	142.5	120	0.47	56.4
6/07/2001	Intensive baiting, blast warrens, spotlight	7.5	MY	19	142.5	120	0.47	56.4
12/07/2001	Tracking	4	JT	20	80	90	0.47	42.3
16/07/2001	Intensive baiting, blast warrens, spotlight	7.5	MY	19	142.5	120	0.47	56.4
17/07/2001	Intensive baiting, blast warrens, spotlight	7.5	MY	19	142.5	120	0.47	56.4
18/07/2001	Intensive baiting, blast warrens, spotlight	7.5	MY	19	142.5	120	0.47	56.4
19/07/2001	Intensive baiting, blast	7.5	MY	19	142.5	120	0.47	56.4

	warrens, spotlight							
Date	**Activity**	**staff hrs**	**Staff involved**	**Rate**	**Total**	**km**	**Fuel**	**Total $ veh**
24/07/2001	Tracking	4	SM	17	68	90	0.47	42.3
25/07/2001	Tracking	5	SM	17	85	90	0.47	42.3
6/08/2001	AoE Meeting	35	MF, JT, SM, NC, DA, MY, PC, DAr	20	700			
14/08/2001	Tracking	4	SM	17	68	90	0.47	42.3
29/08/2001	Tracking	5	SM	17	85	90	0.47	42.3
4/09/2001	Intensive baiting, blast warrens, spotlight	7.5	MY	19	142.5	120	0.47	56.4
5/09/2001	Intensive baiting, blast warrens, spotlight	7.5	MY	19	142.5	120	0.47	56.4
6/09/2001	Intensive baiting, blast warrens, spotlight	7.5	MY	19	142.5	120	0.47	56.4
7/09/2001	Intensive baiting, blast warrens, spotlight	7.5	MY	19	142.5	120	0.47	56.4
13/09/2001	Tracking	4	SM	17	68	90	0.47	42.3
3/10/2001	Tracking	5	SM	17	85	90	0.47	42.3
4/10/2001	LNP, trapping, collar	15	SM, EK	17	255	100	0.47	47
5/10/2001	LNP, trapping, collar	30	SM, JVW, NC, DF	20	600	200	0.47	94
9/10/2001	LNP, trapping, collar	12	SM, EK	17	204	90	0.47	42.3
29/10/2001	Trapping	5	SM	17	85	90	0.47	42.3
30/10/2001	Trapping	7.5	SM	17	127.5	90	0.47	42.3
31/10/2001	Trapping	8	SM	17	136	90	0.47	42.3
1/11/2001	Trapping	8	SM	17	136	90	0.47	42.3
8/11/2001	Trapping	8	SM	17	136	90	0.47	42.3
29/11/2001	Tracking	6	SM	17	102	90	0.47	42.3
30/11/2001	Tracking	6	SM	17	102	90	0.47	42.3
10/12/2001	Trapping	8	SM	17	136	90	0.47	42.3
11/12/2001	Trapping	7.5	SM	17	127.5	90	0.47	42.3
19/12/2001	Trapping	5	SM	17	85	90	0.47	42.3
4/01/2002	Trapping	8	SM	17	136	90	0.47	42.3
10/01/2002	Trapping	7.5	SM	17	127.5	90	0.47	42.3
11/01/2002	Trapping	5	SM	17	85	90	0.47	42.3
12/01/2002	Tracking	5	SM	17	85	90	0.47	42.3
13/01/2002	Tracking	6	SM	17	102	90	0.47	42.3

Date	Activity	staff hrs	Staff involved	Rate	Total	km	Fuel	Total $ veh
14/01/2002	Tracking	6	SM	17	102	90	0.47	42.3
7/02/2002	LNP trapping	16	SM, NC	20	320	150	0.47	70.5
17/02/2002	Trapping	5	SM	17	85	90	0.47	42.3
19/02/2002	LNP, trapping, collar	15	SM, JD	17	255	100	0.47	47
20/02/2002	LNP trapping, collar	15	SM, EK	17	255	100	0.47	47
21/02/2002	LNP trapping, collar	15	SM, EK	17	255	100	0.47	47
24/02/2002	Trapping /tracking	7.5	SM	18	135	90	0.47	42.3
25/02/2002	Trapping / tracking	7.5	SM	18	135	90	0.47	42.3
26/02/2002	Trapping	7.5	SM	18	135	90	0.47	42.3
27/02/2002	Trapping	5	SM	18	90	90	0.47	42.3
29/2/02	Tracking / trapping	6	SM	18	108	90	0.47	42.3
1/03/2002	Trapping	7.5	SM	18	135	90	0.47	42.3
7/03/2002	Tracking / trapping	7.5	SM	18	135	90	0.47	42.3
8/03/2002	Trapping	5	SM	18	90	90	0.47	42.3
4/04/2002	Tracking	8	SM	18	144	90	0.47	42.3
8/04/2002	Tracking	4	SM	18	72	90	0.47	42.3
20/04/2002	Tracking	5	SM	18	90	90	0.47	42.3
7/05/2002	Tracking	7.5	SM	18	135	90	0.47	42.3
2/06/2002	Tracking	3	SM	18	54	90	0.47	42.3
7/06/2002	Tracking	3	SM	18	54	90	0.47	42.3
2002/2003								
27/07/2002	Tracking	7	SM	18	126	90	0.47	42.3
11/08/2002	Tracking	7	SM	18	126	90	0.47	42.3
19/08/2002	Tracking	7	SM	18	126	90	0.47	42.3
20/08/2002	LNP trapping, collar	15	SM, JB	13	195	100	0.47	47
21/08/2002	LNP trapping, collar	5	SM	14	70	100	0.47	47
22/08/2002	LNP trapping, collar	16	SM, BJ	14	224	100	0.47	47
23/08/2002	LNP trapping, collar	7.5	SM	18	135	100	0.47	47
18/09/2002	Tracking / trapping	5	SM	18	90	90	0.47	42.3
19/09/2002	Trapping	7.5	SM	18	135	90	0.47	42.3
12/11/2002	Tracking	6	SM	18	108	90	0.47	42.3
16/02/2003	Tracking / trapping	5	SM	18	90	90	0.47	42.3
17/02/2003	LNp trapping, collar	15	SM, KV	18	270	100	0.47	47

Date	Activity	staff hrs	Staff involved	Rate	Total	km	Fuel	Total $ veh
18/02/2003	LNP trapping, collar	15	SM, KV	18	270	100	0.47	47
19/02/2003	Trapping	5	SM	18	90	90	0.47	42.3
3/03/2003	Tracking / trapping	5	SM	18	90	90	0.47	42.3
4/03/2003	Trapping	15	SM, PP	20	300	90	0.47	42.3
4/05/2003	Tracking	13	SM, RS	19	247	90	0.47	42.3
18/05/2003	LNP trapping	5	SM	20	100	90	0.47	42.3
19/05/2003	LNP trapping	15	SM, RS	19	285	90	0.47	42.3
20/05/2003	LNP trapping	15	SM, RS	19	285	90	0.47	42.3
21/05/2003	LNP trapping	10	SM, RS	19	190	90	0.47	42.3
22/05/2003	LNP trapping	6	RS	18	108	90	0.47	42.3
9/06/2003	Tracking / trapping	5	RS	18	90	90	0.47	42.3
10/06/2003	Trapping	15	SM, RS	19	285	90	0.47	42.3
11/06/2003	Trapping	5.5	SM	20	110	90	0.47	42.3
15/06/2003	Tracking	10.5	SM	20	210	90	0.47	42.3
2003/2004								
28/07/2003	LNP trapping	15	SM, RS	19	285	90	0.47	42.3
29/07/2003	Trapping	15	SM, RS	19	285	90	0.47	42.3
4/08/2003	Tracking / trapping	5	RS	18	90	90	0.47	42.3
5/08/2003	Trapping	7.5	RS	18	135	90	0.47	42.3
14/08/2003	LNP trapping	22.5	RS, JD, SM	19	427.5	100	0.47	47
17/08/2003	Trapping / tracking	6	SM	20	120	90	0.47	42.3
18/08/2003	Trapping	10	RS, SM	19	190	90	0.47	42.3
2/09/2003	Tracking	7.5	RS	18	135	90	0.47	42.3
26/09/2003	Tracking	2	RS	18	36	90	0.47	42.3
20/10/2003	Tracking	3	RS	18	54	90	0.47	42.3
5/11/2003	Tracking	7.5	RS	18	135	90	0.47	42.3
10/11/2003	Trapping	7.5	RS	18	135	90	0.47	42.3
11/11/2003	Trapping	7.5	RS	18	135	90	0.47	42.3
24/11/2003	Tracking / trapping	5	RS	18	90	90	0.47	42.3
25/11/2003	LNP tracking, trap	7.5	RS	18	135	90	0.47	42.3
7/12/2003	Tracking	3	RS	18	54	100	0.47	47
18/12/2003	Aerial tracking	2.5	RS, AF	20	50	90	0.47	42.3
23/02/2004	LNP trapping	5	RS	18	90	100	0.47	47

Date	Activity	staff hrs	Staff involved	Rate	Total	km	Fuel	Total $ veh
24/02/2004	LNP trapping	5	RS	18	90	100	0.47	47
25/02/2004	LNP trapping	7.5	RS	18	135	100	0.47	47
26/02/2004	Trapping	7.5	RS	18	135	100	0.47	47
28/02/2004	LNP trapping	5	RS	18	90	100	0.47	47
29/02/2004	LNP trapping	6	RS	18	108	100	0.47	47
20/05/2004	LNP trapping	22.5	SM, RS, LR	17	382.5	100	0.47	47
21/05/2004	LNP trapping	15	SM, RS, LR	17	255	100	0.47	47
25/05/2004	LNP trapping	10	SM, LR	16	160	100	0.47	47
26/05/2004	LNP trapping	15	SM, LR	16	240	100	0.47	47
27/05/2004	LNP trapping	15	SM, LR	16	240	100	0.47	47
2004/2005								
18/07/2004	LNP trapping	15	SM, CM	18	270	100	0.47	47
19/07/2004	LNP trapping	5	SM	18	90	100	0.47	47
Date	Activity	staff hrs	Staff involved	Rate	Total	km	Fuel	Total $ veh
20/07/2004	LNP trapping	6	SM	18	108	100	0.47	47
21/07/2004	LNP trapping	5	SM	18	90	100	0.47	47
	Total hours	2133.5		Total cost	38586	24220		11383.4
	1998/1999	1999/2000	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005	Total up to Augt. 2004
Total hours	28	797	433	477	243	247.5	31	2228.50
Total cost	560	12668.5	$7,944.50	8643.00	4355.00	4417.00	558	38586.00
For legend of staff initials see next page of table								

Legend to staff initials								
Initial	Name	Initial	Name	Initial	Name	Initial	Name	
MY	Mike Young	PC	Peter Copley	RS	Rachel Stringer	DW	Dave Wray	
MF	Michael Freak	DH	Dave Hackett	LR	Loyd Richards	JSt	Joe Stelman	
JT	Joe Tilley	NC	Nigel Cotsell	CM	Carissa Male	MN	Michael Newchurch	
TG	Tom Gerschwitz	AF	Andrew Freeman	Dar	Dave Armstrong	SW	Stephanie Williams	
JD	Joe Dufek	DF	Dave Farlam	PP	Paula Peeters			
JS	John Simes	GJ	Geoffrey Jones	JB	Jamie Bell			
GG	Graham Goldsmith	BD	Brett Dalzell	CH	Chris Holden			
TB	Tony Berdan	EK	Eva Kelly	DA	Di Ancell			
JVW	Jason van Weenan	BJ	Bettina Jackner	RA	Ross Allen			
BR	Brian Robins	KV	Kerri Villiers	SM	Sheridan Martin			

Appendix 4B: Summary of contractor costs

Bettong contractor monitoring / evaluation expenses							
Funding source							
Date	**Source**		**Amount**				
Jun-00	Nature Con Foundation		$2,500				
Jul-01	WCF		$2,565				
Jul-01	Nat. Cons Found		$3,164				
Jun-01	WCF		$1,710				
Apr-01	Tulka fire reinstatement		$20,000				
		Total grant	**$29,939**				
Week ending	**Hours**	**Kilometres**	**Rate**	**Amount plus GST**	**Amount - GST**	**Running total**	
2004/2005							
Sheridan Martin, Ops 2, 1/7/04 - 31/8/04							
3/07/2004	37.5		18.9		708.75	708.75	
10/07/2004	37.5		18.9		708.75	1417.5	
17/07/2004	37.5		18.9		708.75	2126.25	
24/07/2004	37.5		18.9		708.75	2835	
31/07/2004	37.5		18.9		708.75	3543.75	
7/08/2004	37.5		18.9		708.75	4252.5	
14/08/2004	37.5		18.9		708.75	4961.25	
21/08/2004	37.5		18.9		708.75	5670	
28/08/2004	37.5		18.9		708.75	**6378.75**	
Total hrs	**337.5**						
2003/2004							
Steve Ball, Statistician, April - June 2004							
27 days	**216**		25.46			**5500**	
Flight to PL	**$850**					**850**	

Week ending	Hours	Kilometres	Rate	Amount plus GST	Amount - GST	Running total	
Sheridan Martin, Ops 2, 14.4.04 to 30.6.04							
17/04/2004	22.5		18.9		425.25	425.25	
24/04/2004	37.5		18.9		708.75	1134	
1/05/2004	37.5		18.9		708.75	1842.75	
8/05/2004	37.5		18.9		708.75	2551.5	
15/05/2004	37.5		18.9		708.75	3260.25	
22/05/2004	37.5		18.9		708.75	3969	
29/05/2004	37.5		18.9		708.75	4677.75	
5/06/2004	37.5		18.9		708.75	5386.5	
12/06/2004	37.5		18.9		708.75	6095.25	
19/05/2004	37.5		18.9		708.75	6804	
26/06/2004	37.5		18.9		708.75	**7512.75**	
Total hours	**397.5**						
Ray Carpenter, Staff Easy, August 2003							
17/08/2003	6		25.47	152.82	138.91	138.91	
Total hrs	**6**				**total**	**138.91**	
2002/2003							
Ray Carpenter, Staff Easy, April - June 2003							
4/05/2003	6.5		25.47	165.555	150.49	150.49	
25/05/2003	6.5		25.47	165.555	150.49	300.98	
15/06/2003	16		25.47	407.52	370.44	671.41	
Total hrs	**29**				**total**	**671.41**	
2001/2002							
Tom Bott, Southern Eyre Animal and Plant Control Board, Feb. 2002							
24/04/2002	8		20		151.2	$151.20	

Week ending	Hours	Kilometres	Rate	Amount plus GST	Amount - GST	Running total	
25/04/2002	8		20		160	$311.20	
28/04/2002	8		20		160	$471.20	
3/05/2002	4		20		75.6	$546.80	
		360	0.44		158.4	$705.20	
Total hours	**28**				**total**	**$705.20**	
Dave Cunningham, Staff Easy, 15/10/01 - 27/6/02							
21/10/2001	16		23.42	374.72	340.62	340.62	
28/10/2001	16		23.42	374.72	340.62	681.24	
1/11/2001		565	0.47	265.55	241.38	922.63	
4/11/2001	16		23.42	374.72	340.62	1263.25	
11/11/2001	16		23.42	374.72	340.62	1603.87	
11/11/2001		558	0.47	262.26	238.39	1842.26	
18/11/2001	16		23.42	374.72	340.62	2182.88	
25/11/2001	24		23.42	562.08	510.93	2693.81	
9/12/2001	4		23.42	93.68	85.16	2778.97	
9/12/2001		720	0.47	338.4	307.61	3086.57	
16/12/2001	16		23.42	374.72	340.62	3427.19	
23/12/2001	16		23.42	374.72	340.62	3767.81	
30/12/2001	16		23.42	374.72	340.62	4108.43	
6/01/2002	16		23.42	374.72	340.62	4449.06	
13/01/2002	16		23.42	374.72	340.62	4789.68	
20/01/2002	16		23.42	374.72	340.62	5130.30	
27/01/2002	13		23.42	304.46	276.75	5407.05	
1/02/2002		603	0.47	283.41	257.62	5664.67	
3/02/2002	16		23.42	374.72	340.62	6005.29	
10/02/2002	14		23.42	327.88	298.04	6303.33	
10/02/2002	14		23.42	327.88	298.04	6601.38	

Week ending	Hours	Kilometres	Rate	Amount plus GST	Amount - GST	Running total	
3/03/2002	16		23.42	374.72	340.62	6942.00	
10/03/2002	9		26.64	239.76	217.94	7159.94	
31/03/2002	8		26.04	208.32	189.36	7349.30	
7/04/2002	16		23.42	374.72	340.62	7689.92	
9/06/2002	12		23.42	281.04	255.47	7945.39	
27/06/2002					554.53	8499.92	
27/06/2002					510.98	9010.90	
27/06/2002					974.99	**9985.89**	
Total hrs	**322**	**2446**					
2000/2001							
Lisa Pulman, Prime Placements, 26/7/00 to 20/10/00							
28/07/2000	13		26.52	379.24	344.76	344.24	
11/08/2000	14.3		26.52	422.99	384.54	728.78	
1/09/2000	14.3		26.52	422.99	384.54	1113.32	
6/10/2000	4.3		26.52	131.27	119.34	1232.66	
20/10/2000	10.15		26.52	299.01	271.83	**1504.49**	
Total hrs	**56.05**						
Dave Cunningham, Staff Easy, 26/3/01 - 10/6/01							
1/04/2001	22		25.47	$560.34	$509.40	$509.40	
8/04/2001	30		25.47	$764.10	$694.64	$1,204.04	
15/04/2001	37.25		25.47	$948.76	$862.51	$2,066.54	
22/04/2001	38		25.47	$967.86	$879.87	$2,946.42	
		901	0.36	$324.36	$288.32	$3,234.74	
29/04/2001	31		25.47	$789.57	$717.79	$3,952.53	
6/05/2001	40		25.47	$1,018.80	$926.18	$4,878.71	
		1322	0.36	$475.92	$423.04	$5,301.75	

Week ending	Hours	Kilometres	Rate	Amount plus GST	Amount - GST	Running total	
13/05/2001	26		25.47	$662.22	$602.02	$5,903.77	
		542	0.36	$195.12	$173.44	$6,077.21	
20/05/2001	11		25.47	$280.17	$254.70	$6,331.91	
27/05/2001	28.5		25.47	$725.90	$659.90	$6,991.81	
3/06/2001	36.5		25.47	$929.66	$845.14	$7,836.95	
		1216	0.36	$437.76	$389.12	$8,226.07	
10/06/2001	22		25.47	$560.34	$509.40	$8,735.47	
		374	0.36	$134.64	$119.68	**$8,855.15**	
Total hours	**322.25**						
1999/2000							
<u>Yoeri Mack, OPS2, 2/10/99 to 6/1/00</u>							
16/10/1999	37.5		15.23		571.125	571.13	
23/10/1999	37.5		15.23		571.125	1142.25	
30/10/1999	37.5		15.23		571.125	1713.38	
6/11/1999	37.5		15.23		571.125	2284.50	
13/11/1999	37.5		15.23		571.125	2855.63	
20/11/1999	37.5		15.23		571.125	3426.75	
27/11/1999	37.5		15.23		571.125	3997.88	
4/12/1999	37.5		15.23		571.125	4569.00	
11/12/1999	37.5		15.23		571.125	5140.13	
18/12/1999	37.5		15.23		571.125	5711.25	
25/12/1999	37.5		15.23		571.125	6282.38	
1/01/2000	37.5		15.23		571.125	6853.50	
8/01/2000	22.5		15.23		342.675	**7196.18**	
Total hrs	**472.5**						

Week ending	Hours	Kilometres	Rate	Amount plus GST	Amount - GST	Running total	
Hafiz Stewart, PO2, 2/9/99 to 9/10/00							
4/09/1999	37.5		23.1		866.25	866.25	
11/09/1999	37.5		23.1		866.25	1732.5	
18/09/1999	37.5		23.1		866.25	2598.75	
25/09/1999	37.5		23.1		866.25	3465	
2/10/1999	37.5		23.1		866.25	4331.25	
9/10/1999	37.5		23.1		866.25	**5197.5**	
Total hrs	**225**						
Flight to PL					300		
Accomodation					2900	**8397.5**	
	1999/2000	**2000/2001**	**2001/2002**	**2002/2003**	**2003/2004**	**2004/2005**	**Total for program**
Total hours	697.5	378.3	350	16	619.5	337.5	**2398.80**
Total cost	15593.675	$10,359.64	10691.09	671.41	14001.66	6378.75	**57696.23**

Appendix 4C: Summary of Volunteer involvement

Volunteer assistance			
Date	**Activity**	**Hours**	**Volunteer**
1999/2000			
	Predator control, spotlight	40	MS, SC
	Bettong translocation	15	CT
	Veterinary assistance	4	JC
	LNP Trapping, collar	15	RS
	Fox baiting	196	CS, GS, BW, SW, IA, CA, DJ, BC, HB, TL, GL, JH, RK, BK, BH, JH, CL, KM, TM, SP, AR, PS, LS, KV, MW, JF
	Small vert. survey	140	BW, SW, JF, CS, AR, JC
	Tunarama promotion	7.5	GS, CS, BW, SW, IA, CA, JF, PS, LS, AR
		417.5	
2000/2001			
	Predator control, spotlight	30	MS, SC
	LNP Trapping, collar	15	RS
	Bettong translocation	7.5	RS
	DEH directors grant application	4	BW, CS
	Fox baiting	196	CS, GS, BW, SW, IA, CA, DJ, BC, HB, TL, GL, JH, RK, BK, BH, JH, CL, KM, TM, SP, AR, PS, LS, KV, MW, JF
	Small vert. survey	80	BW, SW, IA, CA, JC, Jco, JF, RS, LS, CS, GT, RCr, CG, HO
	Tunarama promotion	7.5	GS, CS, BW, SW, IA, CA, JF, PS, LS
		340	
2001/2002			
	Spotlight survey	120	MS, SC, **, **
	LNP Trapping, collar	14	LR
	NHT Biodiversity grant	4	BW, CS, IA
	NHT Fox baiting grant	4	BW, CS, IA
	Small vert. survey	140	BW, SW, JC, Jco, CL, MM, GT
	Fox baiting	196	CS, GS, BW, SW, IA, CA, DJ, BC, HB, TL, GL, JH, RK, BK, BH, JH, CL, KM, TM, SP, AR, PS, LS, KV, MW, IP, MP, ST, GT, MM. SO, JF
		478	

Date	Activity	Hours	Volunteer
2002/2003			
	Predator control, spotlight	30	MS, SC
	LNP Trapping, collar	7	GT
	Predator control	15	MS
	Fox baiting	196	CS, GS, BW, SW, IA, CA, DJ, BC, HB, TL, GL, JH, RK, BK, BH, JH, CL, KM, TM, SP, AR, PS, LS, KV, MW, IP, MP, ST, GT, MM. SO
	Small vert. survey	80	MM, DJ, Jco, BW, SW
	Tunarama promotion	7.5	GS, CS, BW, SW, IA, CA, JF, PS, LS, PK, SO, TL
		335.5	
2003/2004			
	Predator control, spotlight	40	MS, SC
	LNP Trapping, collar	15	RC
	Fox baiting	3.5	CS, GS, BW, SW, IA, CA, DJ, BC, HB, TL, GL, JH, RK, BK, BH, JH, CL, KM, TM, SP, AR, PS, LS, KV, MW, IP, MP, ST, GT, MM. SO
		58.5	
2004/2005			
	LNP Trapping, collar	22.5	WS, AI, RP
	Fox baiting	98	
		120.5	
		1750	

Volunteers		**Volunteers**		**Volunteers**	
Initials	**name**	**Initials**	**name**	**Initials**	**name**
MS	Michael Skeates	GD	Gweneth Davies	SO	Shylie O'Brien
SC	Sharron Crowle	CD	Cath Dickie	IP	Ian Phillips
**	unknown	AD	Agnes Dickson	MP	Margaret Phillips
CT	Clee Tonkin	DE	Doug Easson	SP	Steve Pocock
JC	Jenny Chillingworth	LE	Lesley Easson	AR	Angela Reimann
RS	Robyn Spry	BE	Bill Ellis	PS	Peter Sheridan
LS	Liam Spry	TE	Tommy Ellis	LS	Lana Sheridan

Volunteers	Volunteers	Volunteers					
Initials	**name**	**Initials**	**name**	**Initials**	**name**		
RC	Ray Carpenter	JH	Joan Harris	GT	Graeme Tonkin		
WS	William Shaw	JF	Jo Freedenal	ST	Sally Tonkin		
AI	Amy Ide	BH	Barry Hetherington	KV	Kevin Vigar		
RP	Rosie Peak	Jan H	Jan Hetherington	LR	Lana Roediger		
IA	Ian Abbott	TH	Thelma Hodson	CG	Carolyn Gibson		
CS	Cathy Smith	DJ	Dean Jacobs	RCr	Rebecca Crack		
GS	Graeme Smith	RK	Racheal Kunnassarr	Jco	Jane Cooper		
BW	Barney Williams	BK	Bill Kunnassarr	CG	Colin Gill		
SW	Sally Williams	CL	Carmel Langmead	HO	Hazel O'conner		
MW	Matt Williams	HL	Heather Little	HB	Helen Breakey		
BC	Brian Clarke	GL	Greame Lock	JC	Janet Copp		
SB	Stella Brasher	TL	Trish Lock	KM	Karen Mueller		
AC	Andrew Chappel	MM	Murvyn Mason				