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PARKS VICTORIA TECHNICAL SERIES • NUMBER 29 Adaptive Experimental Management of Foxes – Annual Progress Report: July 2004 – June 2005

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Adaptive Experimental Management of Foxes

Annual Progress Report: July 2004 – June 2005

Authors: A. Robley and J. Wright

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WOOD FIBRE FROM SUSTAINABLE FOREST ECF ELEMENTAL CHLORINE FREE EMS ENVIRONMENTAL MANAGEMENT SYSTEMS Printed on environmentally friendly paper

Parks Victoria Technical Paper Series No. 29

Adaptive Experimental Management of Foxes

Annual Progress Report: July 2004 – June 2005

Alan Robley

Arthur Rylah Research Institute for Environmental Research

John Wright

Parks Victoria

February 2006

Parks VICTORIA

EXECUTIVE SUMMARY

The Fox Adaptive Experimental Management (AEM) project was initiated in 2001 by Parks Victoria in partnership with the Arthur Rylah Research Institute for Environmental Research (ARIER) to measure the costs and benefits of a range of fox control strategies. This report presents the results to the end of the fourth year of implementation of the project.

In its fourth year, the project continued to deliver fox baiting at each of the six parks involved as well as monitor bait-take and fox activity. Monitoring of native fauna was also continued at each of the parks.

Major findings to date relate to differences in the effectiveness of different baiting strategies in reducing fox activity. At sites implementing annual baiting programs (Coopracambra and Hattah-Kulkyne National Parks); there has been substantial reduction in bait-take, which has remained low relative to the free-feed period at the start of the program. Levels of bait-take at Coopracambra and Hattah-Kulkyne are very different. This may be a result of a difference in underlying fox density and the landscape surrounding these two parks.

A similar picture is emerging from the pulsed baiting program at Wilsons Promontory National Park where there has been an overall decline in bait-take since the beginning of the poisoning program. The relative level of bait-take at Wilsons Promontory is much higher than that for both Hattah-Kulkyne and Coopracambra. This suggests that factors other than surrounding landscape may influence fox density (eg, reliability of food supply, local habitat complexity). This may in turn have an influence on the intensity of baiting required to manage fox populations. The pulsed program at the Grampians National Park was only initiated in 2003-04 and since summer 2003-04 there has been a steady decline in fox activity

The two seasonal programs (Eumeralla Coastal Reserve, Little Desert National Park) do not appear to be reducing and/or maintaining a reduced level of fox abundance as indicated by bait-take. This is true of both the medium-intensity and the low-intensity baiting programs at the Little Desert National Park.

Sand plot activity monitoring was established to provide an independent measure of the change in the fox populations at each of the parks. The number of plots deployed in each park was limited by the availability of resources to operate them effectively. Analysis of sand plot data has revealed that this level of effort is unlikely to be able to separate out process and measurement error from actual changes in fox activity. In the light of this analysis, the use of sand plot activity monitoring is being reviewed. There are three two possible outcomes from this review, 1) continue monitoring effort and explore the use of alternative analytical techniques to make probability statements about the likelihood a change has occurred, 2) increase the effort (investment) in sand plot monitoring, or 3) cease sand plot activity monitoring and rely solely on bait take as the measure for success.

Many of the difficulties in delivering baiting and monitoring at Discovery Bay Coastal Park in earlier years of the program have also been experienced at Eumeralla Coastal Reserve. In addition, the size and shape of Eummeralla Coastal Reserve allows reinvasion of the reserve at a rate that far exceeds the capacity of the baiting and shooting program to maintain a suppressed fox population. Furthermore, a multitude of factors are affecting the survival of hooded plovers (the target prey species at that site) and this confounds our ability to determine which factors are most important. As a result, this reserve has been removed from the Fox AEM program.

The indication that seasonal baiting has not been able to reduce or maintain a reduced fox population at Little Desert National Park has led to a revaluation of that program. The treatments at this site (seasonal baiting at 2 intensities) form part of the original design of the adaptive management experiment. Under strict adherence to an AEM approach, all

experimental treatments established at the outset of the program would be maintained for the duration of the experiment. However, given the clear lack of suppression in fox activity at Little Desert National Park and the fact that the design of the experiment has already been modified at other sites, Parks Victoria felt that maintaining such a management strategy was not desirable. It was decided therefore to alter this program by changing to either a pulsed or continuous annual program on the one of the blocks currently-baited and to maintain the seasonal program on the other baited block. The nature of these changes is yet to be determined.

Prey-species monitoring was implemented successfully in all parks and while estimated abundance or trap success have increased for some species at some parks, it is not yet clear whether these increases are related to fox control or factors such as climactic conditions, available food resources landscape context or other factors not related to fox control. The increases observed to date are encouraging; however it will be a number of years before we can expect to see any changes in prey species abundance. Initial analysis of the results from other predator control programs suggests that prey species responses will be patchy rather than uniform and that it may take at least 4 – 5 years of consistent fox control before a response is detected.

The Fox AEM project is progressing well and while results suggest differences in the effectiveness of baiting strategies, new issues such as the landscape context and the composition of the residual fox populations, and the relationship between indices and actual changes in abundance are also emerging. Prey species monitoring has produced interesting results, but as was originally noted, it will take a number of years to provide a robust indication of the effectiveness of the different control strategies in increasing prey species populations.

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INTRODUCTION

In 2001, Parks Victoria instigated a project in partnership with the Arthur Rylah Research Institute for Environmental Research (ARIER) to measure the costs and benefits of a range of fox control strategies using an Adaptive Experimental Management (AEM) approach. A detailed explanation of the Fox AEM project is presented in the Methods Section. For further information on adaptive management see Walters (1997).

The Fox AEM project was established in response to recognition by Parks Victoria of the need to increase its understanding of the efficiency and effectiveness of its natural values management program, including different strategies used to control foxes. The range of sites at which fox control is undertaken, and the range of strategies implemented across these sites provided an ideal opportunity for applying an Adaptive Experimental Management approach.

This project is not intended to answer all the questions regarding the control of foxes on the Parks Victoria estate. It is intended to test the applicability of the AEM approach to pest management in Victoria's parks and reserves, as well as to examine some aspects of the effectiveness and efficiency of different fox control strategies. If the project is successful, the approach could be expanded to build a greater understanding of the best ways to deliver effective and efficient fox control.

This document is the fourth annual progress report and provides data and information on the project to date. Results on the effectiveness of the fox control programs in reducing fox activity for each park and the continued monitoring of native species responses are presented. This report also identifies issues experienced in implementing the AEM approach, describes changes made to the original project design and suggests actions for the further implementation and improvement of the Fox AEM project.

OBJECTIVES

The objectives of the Fox AEM project are to determine;

1. The applicability of the AEM approach to pest management in Victoria's parks and reserves,
2. The relative effectiveness and efficiency of different fox control strategies by implementing a program that will:
   - *Measure the effects of different combinations of spatial and temporal intensities of fox control on fox activity and on the responses of prey species.*
   - *Measure the costs of each fox control strategy and ultimately compare the costs and benefits of the different strategies.*
   - *Assess the effectiveness of the AEM approach to landscape-scale pest management.*

This is the fourth annual report for the Fox AEM program and updates information on the progress of the project. It is not intended that this report fulfils the above objectives, rather it aims to present information on the progress of the program.

METHODS

Overview

The design of the project was developed through a series of workshops involving staff from Parks Victoria and ARIER. These workshops identified Parks Victoria objectives for fox control, the range of control techniques applied and the questions Parks Victoria wished to address through the fox AEM project. The proceedings of these workshops describe the process undertaken and the questions identified (Choquenot and Robley, 2001a, 2001b).

A central component to AEM programs is for the management agency to use features of experimental design to obtain reliable knowledge about management activities. Ideally, the treatments applied at each park should have been allocated at random (Sit and Taylor 1998), which would allow for generalisation of the results. This was not possible due to the large scale of the control operations and the desire of managers to implement programs consistent with historic or proposed control strategies for each site. Pre-treatment assessments of fox and native species abundance would have allowed stronger inferences to be made about the effectiveness of the control operations. A number of parks have treatment and non-treatment sites that will allow for comparisons of trends to be assessed. However, pre-treatment variation between treated and non-treated sites can not be accounted for *a priori* and thus makes interpretation of differences in treatment and non-treatment sites problematic. We have attempted to replicate the timing and intensity of treatments; however, this was not possible for all combinations of timing and intensity of treatments due to some pre-existing control programs.

Study Sites

Six parks are involved in the Fox AEM project. These parks either had existing fox control operations or had a new program designed to suit this AEM project. The parks are:

- *Coopracambra National Park*
- *Eumeralla Coastal Reserve*
- *Grampians National Park*
- *Hattah-Kulkyne National Park*
- *Little Desert National Park*
- *Wilsons Promontory National Park*

Originally, the project included Discovery Bay Coastal Park, however this site was excluded from the project at the end of 2002-03 and an alternative site was established in Eumeralla Coastal Reserve on the nearby Codrington coast. At Discovery Bay, highly energetic tides result in Hooded Plovers (the target species) nesting far back in the secondary dune system, making monitoring changes in nest and fledgling success impossible. In addition, bait stations are constantly eroded and baits are lost due to tidal movement. While protection of Hooded Plovers remains a concern at the site, the difficulty in implementing control and monitoring programs means that little would be gained from retaining this site as part of the overall AEM project.

Fox Control

At each of the parks involved in the project, a specific combination of timing and spatial intensity of fox control using 1080-poisoned baits is being implemented (Table 1). The timing of baiting operations has been divided into three categories,

Timing:

1. Continuous - annual programs. Baits are checked and replaced every two to three weeks throughout the year.
2. Continuous - seasonal programs. These programs bait on a continuous basis but the baiting occurs within a specific period each year. The period during which baiting occurs is dictated by a number of factors including the timing of available resources, seasonal access to areas, or the period a prey species is thought to be most at risk from predation.
3. Pulsed programs. This strategy is specific to Wilsons Promontory National Park and the Grampians National Park baiting programs. Baiting is continuous for a specific period with a break of several weeks between ‘pulses’ of baiting.

Note that in the first 2 years of the Fox AEM project and in the 5 years prior, the baiting program at the Grampians National Park was focused around the perimeter of the park. Data from the perimeter-baiting program were examined and the results presented in the 2002 - 2003 annual report (Robley and Wright 2003). It was apparent from these data that there had been no decline in bait-take over 7 years and it was likely that this program was simply harvesting surplus foxes. In December 2003, this program was changed to a pulsed baiting program that operates in internal areas of the park.

Spatial Intensity:

Spatial intensity of baiting is measured by the number of baits laid per square kilometre and is also divided into three categories,

- High >0.6 baits/km2
- Medium 0.2 - 0.6 baits/km2
- Low <0.2 baits/km2

These 3 categories of intensity are relative to the parks involved in the project and reflect the range of control activities in place across the Parks Victoria estate at the beginning of the Fox AEM project. A full description of the baiting programs is given below.

Table 1. The fox control strategies being implemented in the Fox AEM project.

Intensity	Timing		
	Continuous – annual	**Continuous – seasonal**	**Pulsed**
High	Hattah-Kulkyne NP [A]Deliverance West Coast	*Eumeralla CR	Wilsons Promontory NP – Isthmus #Grampians NP – Red Rock
Medium	Deliverance East Coast Deliverance Stony Peak	Little Desert NP - Eastern Block	Wilsons Promontory NP – Central **Grampians NP – Internal
Low	Coopracambra NP	Little Desert NP - Central Block	Wilsons Promontory NP – South

*This program will not remain part of the Fox AEM project from 2005-06. ** This program began in December 2003. # This program has been incorporated into the internal Grampians baiting program. [A]Project Deliverance was conducted by DSE-Orbost Region and finished in 2005. While not part of the fox AEM project, it provides additional data against which results obtained may assessed.

Baiting Programs at each Park

Coopracambra National Park

Prior to the establishment of the Fox AEM project, there was no fox control undertaken in the park. The program originally covered 118 km of track with 75 bait stations spaced at 1.2 – 1.5 km intervals. However in 2004/05, bait stations along Yambulla Peak track were closed down due to concerns of Park management for the state of the track, and safety concerns over access along this steep and remote track during periods of wet weather. This removed six bait stations from the program. At this site, 1080-poisoned FoxOff™ baits are buried 12-15 cm below the surface in specifically constructed bait stations and baits stations checked and all baits replaced every three weeks.

Hattah-Kulkyne National Park

The baiting program covers approximately 60% of the park, with the remaining 40% acting as the experimental control, or non-treatment site. Baiting began using free feeds initially and then 1080-poisoned liver on a continuous, annual basis with 137 bait stations spaced at 1-km intervals and stations checked and replaced every two to three weeks. As of May 2004 liver has been replaced with 1080-poisoned FoxOff™ to comply with Department of Primary Industries policy.

Little Desert National Park

The Little Desert has been divided into three discrete sites;

1. The Eastern Block is 477.8 km^2 containing 220 km of internal and perimeter tracks. This site has 137 bait stations are spaced at approximately 1.5 km intervals.
2. The Central Block is 451.2 km^2 with 132 km of track. There are 88 bait stations placed 1.5 km apart.
3. The Western Block is 374.1 km^2 and is a non-treatment site that acts as an experimental control.

The baiting program runs from approximately October/November to March/April with bait stations checked and baits replaced every three to four weeks. The program at this site has been under review and changes are proposed for 2005-06.

Eumeralla Coastal Reserve

This program was established in 2003-04 to replace the baiting program at Discovery Bay Coastal Park which was removed from the Fox AEM project due to difficulties in implementing baiting and monitoring. The focus of the baiting program at Eumeralla is the protection of nesting shorebirds (Hooded Plover). A seasonal baiting program using 1080-poisoned FoxOff™ baits, runs from October / November to March / April each year. Bait stations are located along the northern (inland) boundary of the reserve and along the beach. Bait stations are spaced at 1 km intervals covering approximately 44 km and these are checked and replaced every two weeks.

Monthly spotlight shooting by a professional shooter is used to supplement this program. Shooting is carried out on several private properties that adjoined the northern boundary of the reserve. Note that this program will not remain part of the Fox AEM project in 2005-06.

Grampians National Park

The baiting program at the Grampians National Park was altered in June 2003. Prior to that, a perimeter-baiting program had operated since 1997. That program was assessed as having little long-term effect on fox abundance (see Robley and Wright 2003 for details). The current program consists of baiting 444 km of internal tracks, with 407 bait stations placed at 1 km intervals. Pulses of baiting occur four times per year beginning in mid-winter, mid-spring, mid-summer and mid autumn, with a four-week break between pulses. During each pulse, baits are checked weekly and replaced two times over a period of nine weeks. Factors determining the number of pulses per year were the availability of staff and track access at particularly times of the year. However, the four pulses cover critical times in the life history of foxes, i.e., winter breeding and summer dispersal.

Wilsons Promontory National Park

Wilsons Promontory has been divided into four management areas:

1. The Yanakie Isthmus, which is a high intensity baiting area,
2. The Central section, which is a low intensity baiting area,
3. The Southern section, which is a medium intensity baiting area.
4. The North-east section, where no fox control is done.

The baiting program consists of pulsed baiting using 1080-poisoned FoxOff™ baits, with bait stations at 1-km intervals. A total of 158 bait stations are operated within the park, with 48 in the Isthmus, 88 in the Central area and 22 in the Southern section. There is no free feeding, and liver bait is used on beaches when increased amounts of beach-wash are available. A pulse of baiting lasts for 6 – 8 weeks. At the end all baits not taken are retrieved and replaced at the beginning of the next pulse approximately eight weeks later. Baits are checked every week during a pulse with taken baits replaced.

Non-treatment Sites (no fox control)

Fox activity patterns and prey response can show year to year variation making interpretation of changes in fox activity and prey response difficult in the short term. To improve the ability to infer change related to fox control, a number of non-treatment (no baiting, experimental control) sites have been established. These will act as reference points against which changes in fox activity and potential prey responses can be measured to aid interpretation of the variation in fox and prey responses from year to year due to factors other than effects of fox control (Table 2).

It was not possible to establish non-treatment sites for each treatment or at each park due to logistic constraints. Non-treatment sites have been established at Hattah-Kulkyne and Little

Desert National Parks for both changes in fox and prey species abundance and at the Grampians National Park for changes in fox abundance only. There is potential to implement a non-treatment site in the north-east section of Wilsons Promontory National Park however access to this location is difficult. It would be possible to establish prey response monitoring at the non-treatment site in the Grampians, however financial and logistic constraints prevent this.

Table 2. Parks with areas that are designated non-treatment sites.

Park	Location of non-treatment (control) sites	Baiting programs non-treatment sites provide control for
Hattah-Kulkyne NP	Eastern section of park	Western section annual High intensity baiting program
Grampians NP	Outside internal baiting area	Pulsed baiting program covering internal area
Little Desert NP	Western Block	Seasonal Eastern (Medium) and Central (Low) Blocks baiting

Response of Foxes

Initial Knockdown

The percentage of baits taken over time is often used to measure the effectiveness of a control program. This is calculated by dividing the number of baits taken by the number of baits available and standardised by the number of days between checks. This takes into account that some bait was not available and that the time baits were available varies between checks. The advantage of using percentage bait-take is in its operational efficiency, it is simple to calculate and data are collected in the course of implementing the control program. This measure is particularly useful where there has been a period of free feeding (Coopracambra and Hattah-Kulkyne National Parks) prior to fox control operations (Saunders *et al.* 1995).

The effectiveness of the initial knockdown period was analysed by comparing the difference between indices recorded before (i.e., during the free feed period) and after poison baiting had commenced this was taken to quantify the effect of 1080 poisoning on fox populations. The mean bait-take was first arcsine transformed prior to being compared using Student's t-test (Zar 1999). Pre- and post-baiting sample variances were compared for homogeneity using Bartlett's test before *t*-tests were used to determine the effects of the 1080 poisoning campaign (Fry 1994).

We treated the data in the same manner and used ANOVA to compare differences in bait take between years at Little Desert and between pulses at the Grampians and Wilsons Promontory National Parks (Zar 1999).

Changes in Fox Activity

Fox activity monitoring using sand plots is used to measure the effectiveness of control operations independent of bait-take. Fox activity is monitored before and after seasonal control operations or periodically during continuous programs by recording the presence of fox prints on sand plots. Sand plot monitoring involves laying sand across low use vehicle and walking tracks and checking the sand plots periodically to record the presence of species prints. The proportion of plots with fox sign over a three-day period is used to assess levels of activity. We calculated the 95% confidence limit around the proportion of sand plots with activity using the formulae in (Zar 1999). Non-overlapping confidence limits indicate a significant difference in activity.

Response of Native Species

To determine which of the combinations of timing and intensity of fox control being tested in the Fox AEM project produce a positive biodiversity gain, a set of monitoring protocols for species considered as being at risk from fox predation has been developed (Robley and Choquenot*.* 2002).

To be able to detect a doubling of the population over a several year period it was determined that seven trap sites operated over two sampling sessions each in late spring early summer would provide sufficient data to assess changes in abundance. We anticipate that this level of effort will be sufficient to do so with 85% confidence that a change has taken place and that we have not erroneously concluded an increase had occurred. However, the monitoring protocols will not allow us to determine a causal relationship between the fox control strategies being implemented, but rather if there are associations between a particular strategy and a prey response.

Prey Species Monitoring

Sites for prey species response monitoring within each park were selected on the basis of either records in the Atlas of Victorian Wildlife, suitability of habitat based on descriptions in the literature of species habitat requirements, local knowledge provided by Parks Victoria staff, or a combination of all three.

Seven sites were established at Coopracambra, Wilsons Promontory and the Grampians National Parks, while 21 sites were established at Little Desert National Park (7 in each of 3 blocks) and 14 sites were established at Hattah-Kulkyne national Park (7 in the baited area and 7 in the non-baited area) (Table 3). Monitoring at Eumeralla Coastal Reserve occurs over most of the baited area.

Cage traps were used in the Grampians, Wilsons Promontory and Coopracambra to assess changes in prey species abundance. At each trap site within the park, traps were laid out in three lines of 10 traps, with traps spaced a 25-meter interval and lines spaced at 50-meter intervals. Traps operated for several nights over two sessions with a minimum of two weeks and a maximum of four weeks between sessions.

At the Grampians National Park an additional four sites were selected for monitoring Smoky Mouse, Heath Mouse and Pygmy Possum. At each of these sites, 20 Elliott traps were positioned on the ground and spaced at 25 metre intervals in two lines of ten traps. Lines were separated by 50 metres. All traps were baited with a blend of honey, peanut butter and oats and monitored for several nights.

Traps were covered with a plastic bag; placed under shrubs to provide shelter and some nesting material placed inside each trap. All traps are visited as close to dawn as possible to reduce trap-induced stress. All trap-deaths are recorded as specimens lodged with the Museum of Victoria.

Pit-fall traps were used at the Little Desert and Hattah-Kulkyne National Parks. At each trap site, two lines of 20 buckets (290 mm diameter x 400 mm deep) were placed 10 metres apart. Each bucket was individually numbered. A ‘Y’ shaped fibreglass flywire drift-fence, held erect by steel pegs, was placed over each bucket. The arm of each section of the ‘Y’ extended 2 metres from the centre of the bucket. Buckets were not baited and were monitored daily for several nights. Animals were individually marked to enable recaptures to be identified and to facilitate data analysis. Buckets were operated over several nights for two sessions with a minimum of two weeks and a maximum of four weeks between sessions. Nesting material (small polystyrene cups or cardboard rolls) was provided in all traps. At these sites the herptofauna was grouped based on Agamids (dragon) Gekkonids (geckos) Pygopodids (lizards) Scincids (skinks) and snakes (families have been grouped into one class) to make summarising the data easier.

In all cases, captured animals were individually marked, weighed and sexed. Medium-sized mammals were marked with passive implant transponders (PIT-tags). Each transponder has an individual alphanumeric code to allow individual capture histories to be determined. Small mammals had a small section of outer coat fur clipped and the location on the body noted, to enable recaptures to be identified and facilitate data analysis. Reptiles and amphibians were marked with a small spot of correction fluid.

We estimated N (number of individuals) for medium-sized mammals at Coopracambra, Wilsons Promontory, and the Grampians National Park using a modified version if the Schumacher method (Caughley 1977). This approach requires animals to be marked on several occasions and estimates the population size from the rate at which the proportion of marked animals are captured rises as more animals are marked. Our intention was to use the Peterson method for small mammals and reptiles. This approach requires that recaptures only are identified however, sample sizes were often too small. Where sample sizes of animals were too small to estimate number of individuals, we used captures per 100 trap nights as an index of abundance.

Monitoring at Eumeralla Coastal Reserve used the protocol for monitoring Hooded Plovers developed by Weston and Morrow (2000) and details are given in their report and in Ressom (2001). Briefly, the method used to survey Hooded Plover nest success at Eumeralla Coastal Reserve involved searching for and rechecking nests weekly over the period September – March, covering as much of the area in which fox baiting occurs as was feasible. For each nest, the presence of eggs and chicks was recorded when first detected, and the fate of nests, eggs and chicks was recorded on subsequent visits. As far as possible, the timing and duration of searches was kept consistent each month.

Two approaches were adopted to locate nests, 1) observing the behaviour of adult birds, and 2) methodical searches of suitable habitat. Once a nest was located, its location was recorded on a Global Positioning System to allow the nest to be quickly rechecked at a later date. Flagging tape was used to mark the general location of the nest, but was placed several metres away from the nest.

Table 3. Detection techniques used at each park, the number of sites selected and the nominal target species for each park.

Park	Detection Technique	Number of trap sites	Target Species
Hattah Kulkyne NP	Pitfall bucket traps	14 (7 treatment, 7 non-treatment)	Mallee Ningaui Mitchell's Hopping Mouse Variety of herptofauna
Little Desert NP	Pitfall bucket traps	21 (7 in each of the three blocks)	Silky Mouse Western Pygmy Possum Variety of herptofauna
Grampians NP	Elliott traps Cage traps	4 7	Long-nosed Potoroo Southern Brown Bandicoot Smoky Mouse Heath Mouse
Eumeralla Coastal Reserve	Nest, egg and chick survival	20 km coast line	Hooded Plover
Wilsons Promontory NP	Cage traps	7	Long-nosed Potoroo Southern Brown Bandicoot
Coopracambra NP	Cage traps	7	Long-nosed Bandicoot Ringtail Possum Long-nosed Potoroo Southern Brown Bandicoot

RESULTS

Fox Control – Annual Programs

Hattah-Kulkyne National Park

Bait-take

Although fox control at Hattah-Kulkyne was planned as a continuous, annual program, it has been punctuated by periods where baiting was not undertaken (Figure 1) due to discontinuity in staff and resources available. This highlights one of the difficulties in implementing continuous baiting programs over the long term. The impact of this disruption on the overall effectiveness of the control program is difficult to determine. One consequence of discontinuity in the control program may be immigration into the baited area by foxes from outside the park. It is likely that the ecotone between the natural habitats of the park and the adjacent agricultural habitats provide a diversity of food resources for foxes. Foxes from these ecotonal areas would provide a ready source of immigration into the Park.

The percentage mean daily poison bait take (0.17 ± 95%CI 0.30) remains lower than during the free feed period (0.37 ± 95%CI 0.25; 41% difference), although the variation during the free feed period leads to overlapping 95% confidence limits.

There was a significant difference (t = 7.13, d.f. = 73, p = >0.001) in mean daily bait take between the period of liver baiting (0.21 ± 95%CI 0.0035) and FoxOff baiting (0.42 ± 95%CI 0.0045).

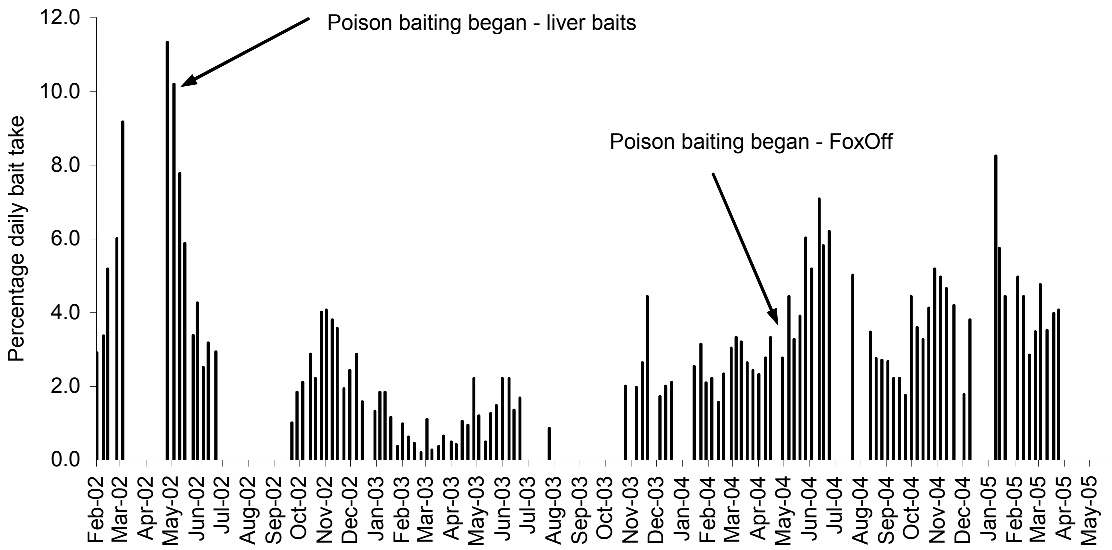

Figure 1. Percentage Daily Bait-take at Hattah-Kulkyne National Park.

Activity monitoring

Fox activity in the baited area at Hattah-Kulkyne decreased markedly (89%) after the poison baiting program began in late March 2002 (Figure 2) and has generally remained lower than during the free feed period as indicated by the non-overlapping 95% confidence limits.

Activity on the non-treated site has generally remained no different throughout, with the exception of September-02 and November-03 when activity was less than seen during the free feed period.

Interestingly, while bait take showed a marked increase in May-04 following a change in bait type, activity (proportion of plots with fox sign) did not increase, and was relatively low. This could be interpreted as bait-averse resident foxes caching the new bait; however, this is an unlikely scenario. A more plausible explanation might be that the number of sand plots being used is insufficient to detect anything but very large shifts in activity. This is reinforced by the highly variable nature of the data.

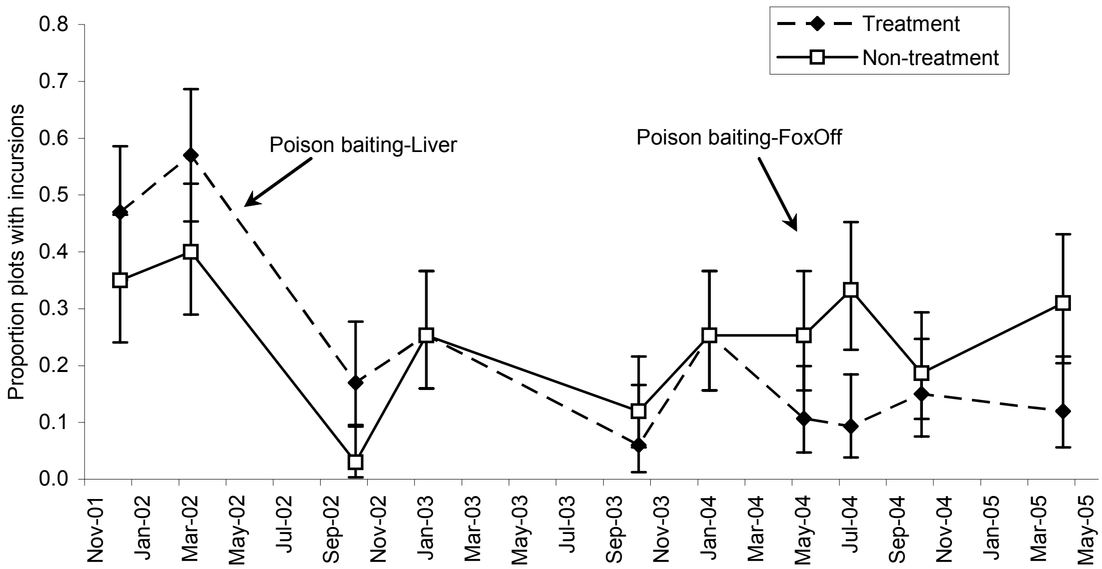

Figure 2. Fox Activity at Hattah-Kulkyne National Park. Data are the proportion of sand plots with fox sign. Bars are 95% confidence limits.

Coopracambra National Park

Bait-take (Foxes)

A free feed period using non-poisoned FoxOff™ baits was undertaken between December 2001 and late January 2002 and poison baiting began in January 2002. The continuity of the baiting program has been maintained with a combination of contract and Parks Victoria staff. At times there has been discontinuity in contracts, creating periods when baiting was undertaken by Parks Victoria staff or when this was not possible, not done at all (Figure 3). Mean daily poison bait take during the poison period (0.36 ± 95%CI 0.11) remains lower than during the free feed period (0.84 ± 95%CI 0.48; 48% difference), although the variation during the free feed period leads to overlapping 95% confidence limits.

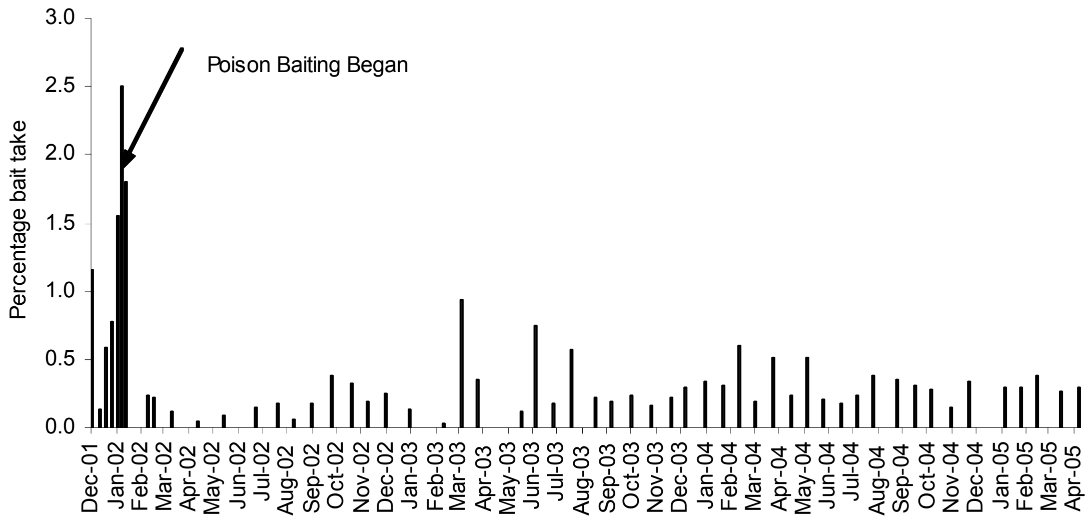

Figure 3. Percentage daily bait-take for foxes at Coopracambra National Park.

Bait-take (Dogs)

Bait-take attributed to dogs during the free-feed period was more consistent than for foxes (Figure 4). Bait-take during the free-feed period was assessed weekly. This frequency of inspection may have been adequate to allow contractors to determine the species that had dug up the bait; however it is important to note that the ability to differentiate fox and dog sign reliably varies with the experience of the operator. We have assumed the operators' experience was sufficient to correctly distinguish fox and wild dog prints. If operators were able to differentiate bait-take by foxes and dogs reliably, then the consistently low level of bait-take after the commencement of poisoning would suggest that this poisoning program has reduced the abundance of wild dogs (Dingoes and their hybrids).

There has been no recorded bait take by wild dogs since August 2004, this may represent a difference in the ability of particular operators to confidently determine differences in species of predator that have taken bait.

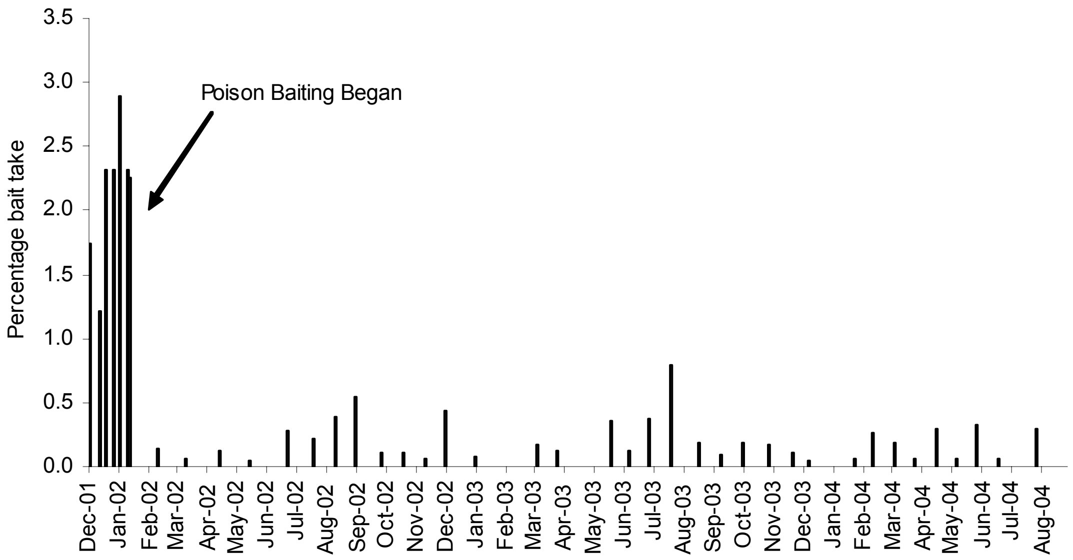

Figure 4. Percentage daily bait-take for dogs (Dingoes/Wild Dogs) at Coopracambra National Park.

Activity monitoring (Foxes)

Fox activity monitoring is scheduled to be undertaken four times per year, i.e., once every three months (Figure 5). However, as a result of weather making access difficult or lack of availability of staff or contractors this schedule has not been met each year. Poison baiting began in late January 2002. Fox activity was measured twice prior to poisoning. Following the instigation of poison baiting fox activity declined, however it has remained variable and this variance confounds the interpretation of the impact the poisoning program has had on the level of fox activity. For example, of the ten sampling periods since poison baiting began activity has been lower than during the pre-poisoning period only 3 times.

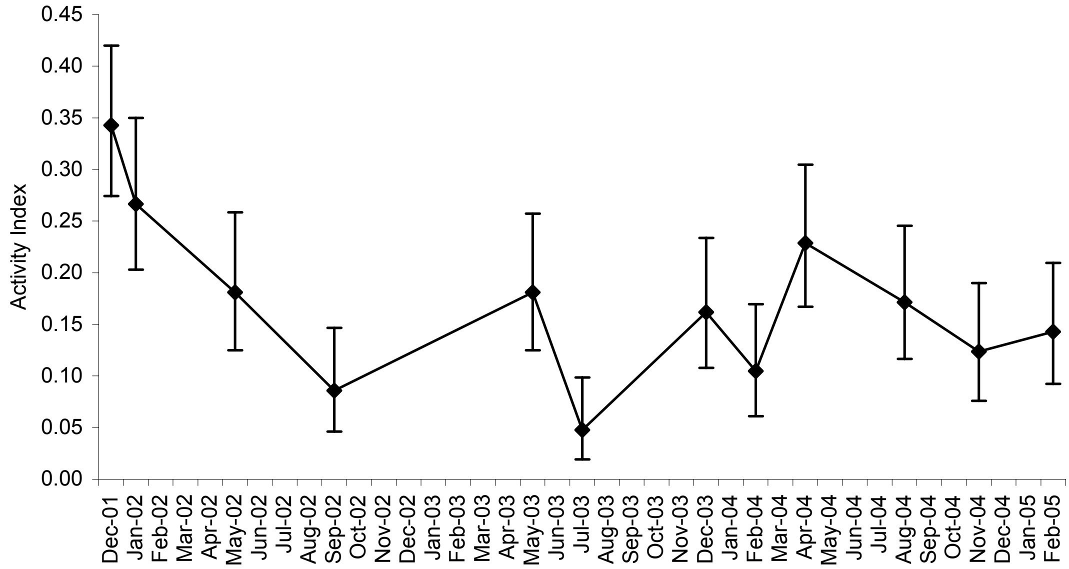

Figure 5. Proportion of sand plots with fox sign at Coopracambra National Park. Poison baiting began in late January 2002. Bars are 95% confidence limits.

Activity monitoring (Other predators)

The identification of wild dog tracks is a skilled task and can be problematic. We have not analysed data on wild dog activity formally given the degree of uncertainty around the prints identified as wild dogs. There is a high degree of variability in reported dog activity and there is no real discernible trend in the data. This may be a reflection of the highly mobile nature of wild dogs (typically they have home ranges 3 times as large as foxes) or the difficulty in differentiating between fox and dog tracks or a combination of both.

Feral cat tracks have been recorded on sand plots on 7 of the 10 sampling occasions. There are significant behavioural differences between feral cats and foxes and wild dogs, and the sand-plot monitoring program is not designed to detect changes in feral cat activity.

Fox Control - Seasonal Programs

Little Desert National Park

Bait-take

Three different treatments are applied at Little Desert National Park, with baiting being applied at different intensities in the Central and Eastern Blocks of the park, and the Western Block acting as a control site. There was no free feeding prior to the commencement of the Fox AEM project as this program was already under way.

Sustained Control

We analysed the pattern in percentage daily bait take across the four years (01/02, 02/03, 03/04, and 04/05) for each treatment block (Eastern and Central) separately (Figures 6 and 7).

Percentage daily bait take was lowest in 01/02 in the Eastern Block, however there has been no detectable long-term reduction in percentage daily bait take over the past 4 years ($F_{3, 32}$ = 3.25, n.s.). Bait take in the Central Block remained constant across all 4 years ($F_{3, 28}$ = 1.06, n.s.)

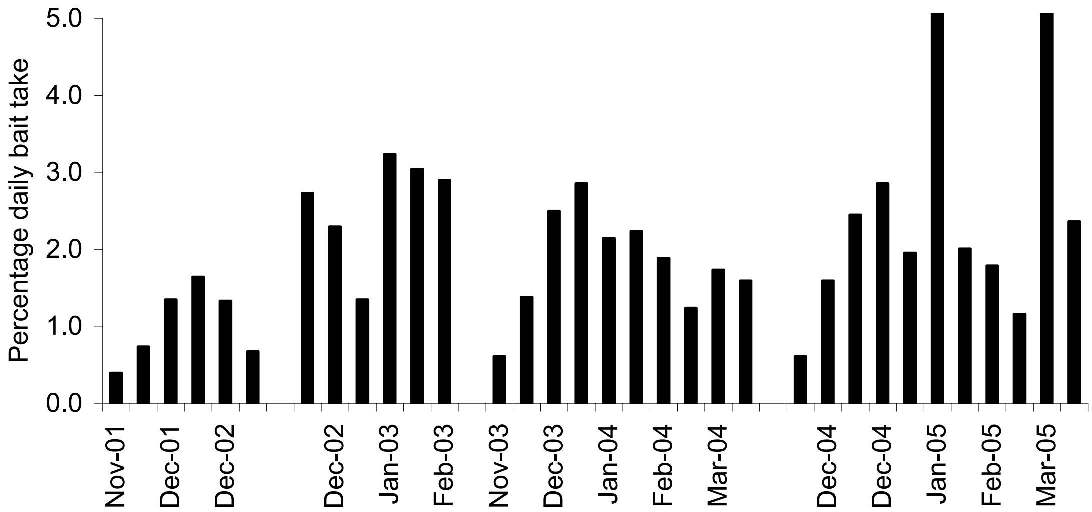

Figure 6. Percentage daily bait-take on Eastern Block (medium intensity) at Little Desert National Park over the first 4 years of the Fox AEM project.

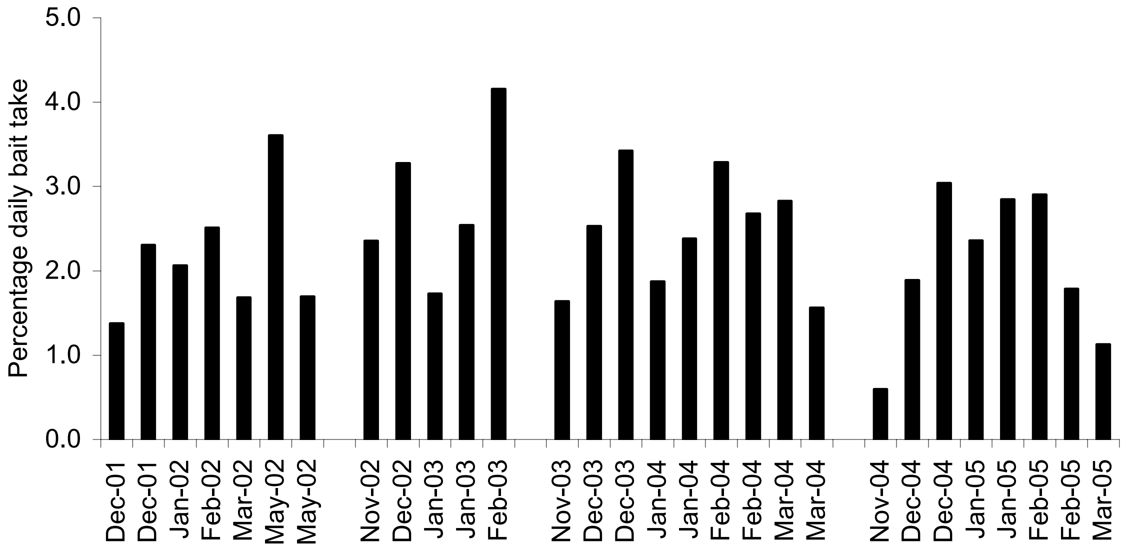

Figure 7. Percentage daily bait-take on Central Block (low intensity) at Little Desert National Park over the first 4 years of the Fox AEM project.

Activity monitoring

There has been no detectable difference in the proportion of sand plots with fox sign between years on any of the Blocks in the Little Desert (Figure 8a-c).

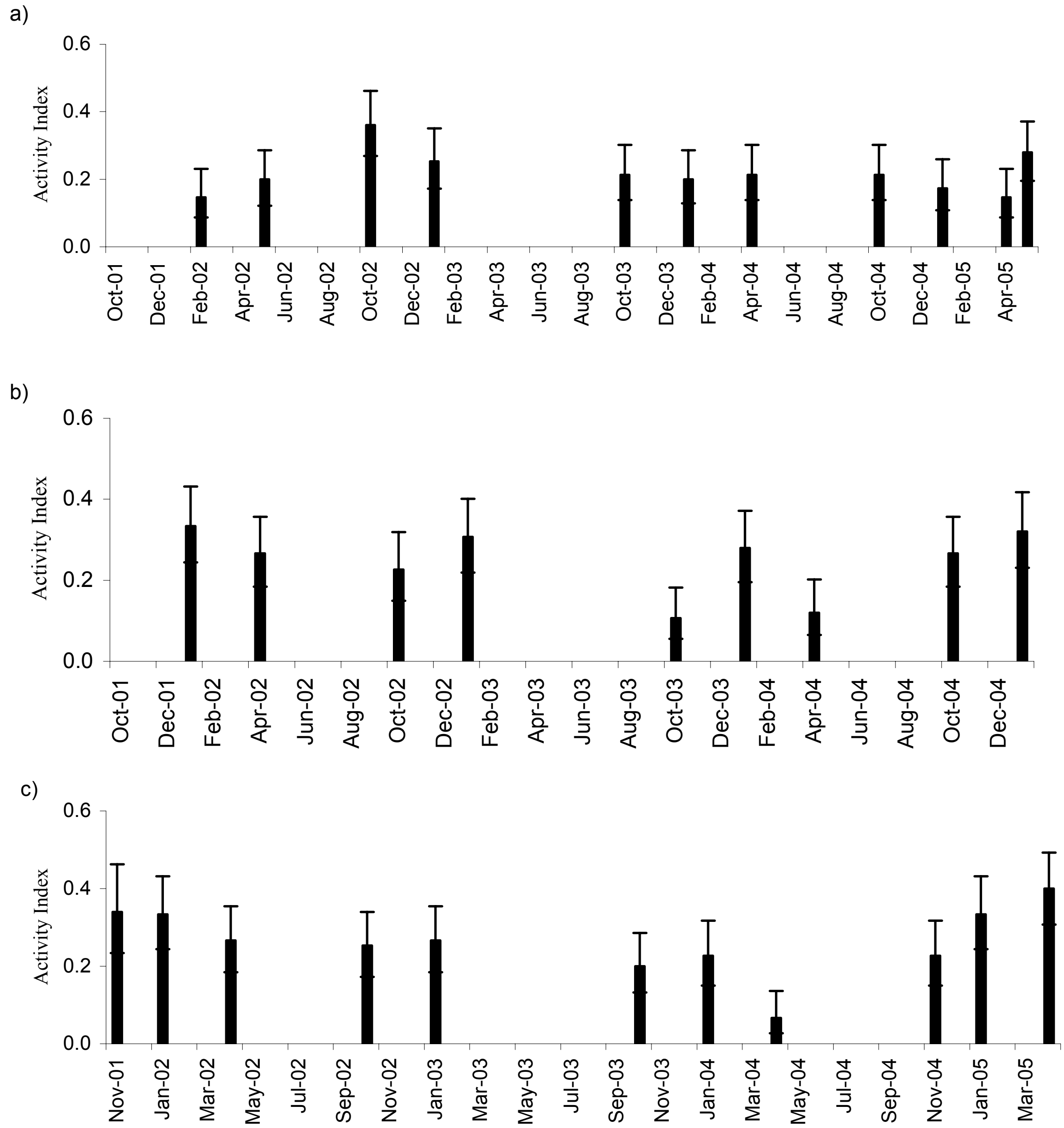

Figure 8. Proportion of plots with fox sign in a) Eastern Block, b) Central Block and c) Western Block of Little Desert National Park. Bars are 95% confidence limits.

Eumeralla Coastal Reserve (Codrington)

Bait-take

Bait-take was variable across the program with no overall decrease in percentage daily bait-take being evident through time (Figure 9). Mean percentage daily bait take in the first year of baiting at this site was 2.02 ± 95% CI 0.55 and in the second year it was 1.95 ± 95% CI 0.53.

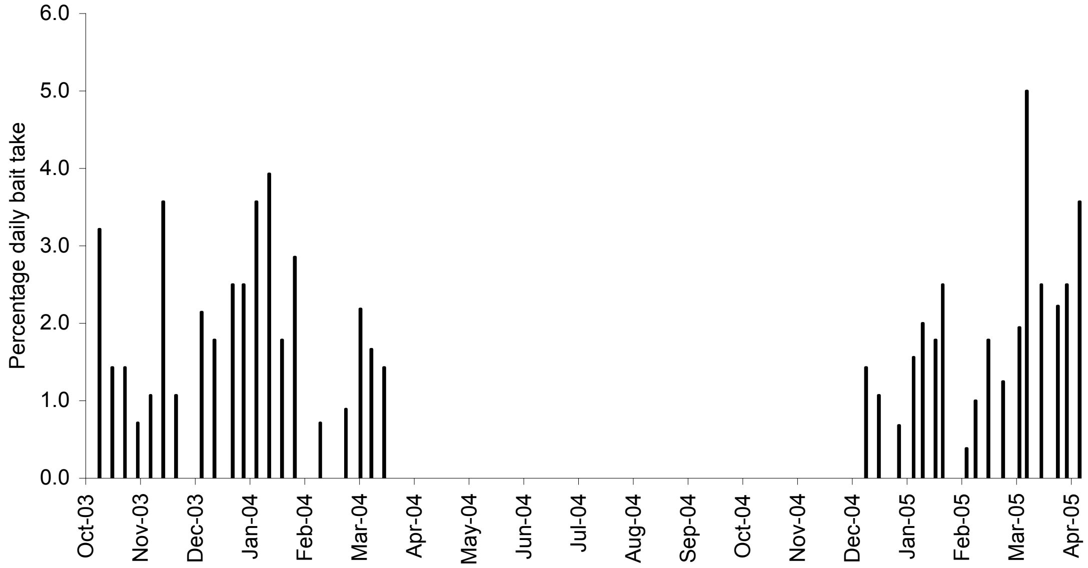

Figure 9. Percentage daily bait-take at Eumeralla Coastal Reserve.

Fox control (shooting)

The unique geographical configuration of Eumeralla Coastal Reserve, a linear coastal strip no wider than 1 km and backed by farming enterprises, and its size (1515 ha) allows the additional control tactic of shooting that would not necessarily be used in much larger parks. Shooting was conducted between November 2003 and February 2004 and October 2004 and March 2005 on the private property adjoining the reserve. This coincided with the poison-baiting program. A licensed professional shooter operated over 51 nights on 7 properties (31 nights – 03/04, 24 nights – 04/05). The date, sex, estimated age and location of all foxes shot was recorded.

A total of 90 foxes were shot, 29 females and 49 males. Foxes were separated into age classes based on the age assigned to them by the shooter in 2003-04 only. The number of foxes shot in each age class from the first year is shown in Figure 10. The majority of foxes that were shot (59%) were pups.

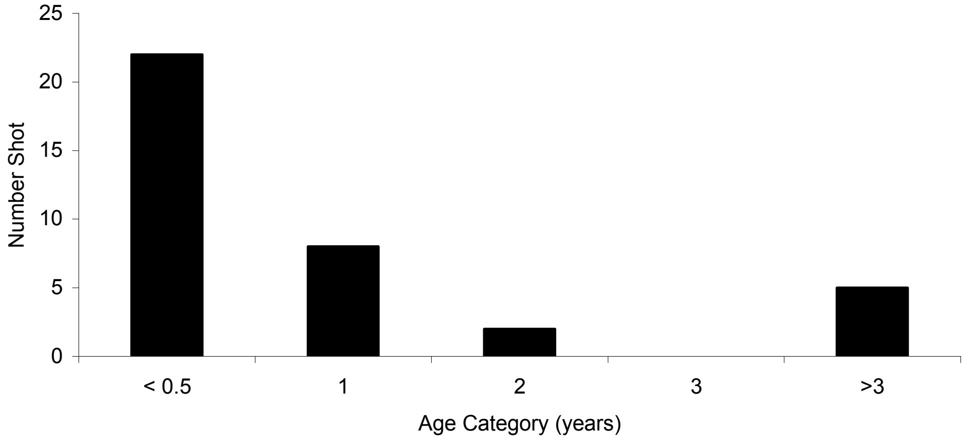

Figure 10. Age distribution (years) of foxes shot adjacent to Eumeralla Coastal Reserve in 2003-04.

Activity monitoring

Fox activity showed no detectable difference from beginning to end of the Hooded Plover breeding season (Figure 11).

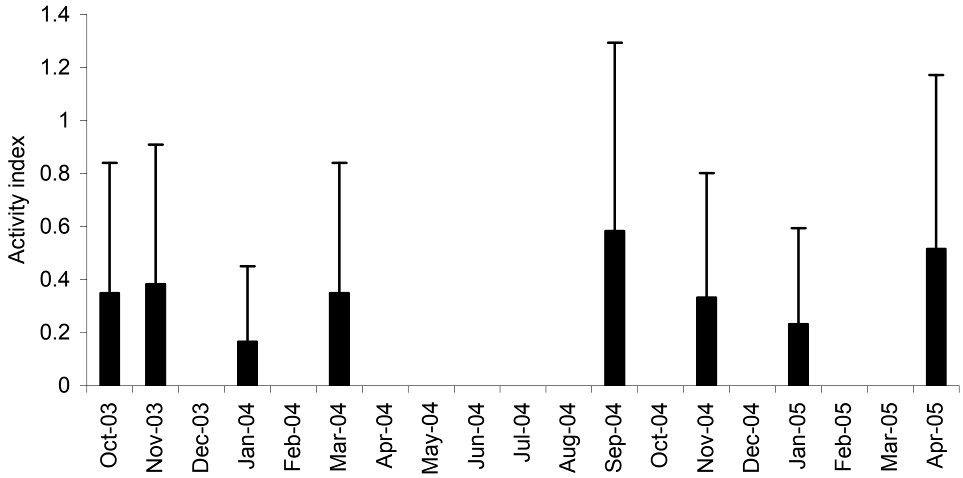

Figure 11. Proportion of sand plots with fox sign at Eumeralla Coastal Reserve.

Bars are 95% confidence limits. Note monitoring was undertaken over only two days in January-04 due to bad weather.

Fox Control - Pulsed Programs

Grampians National Park

Bait-take

An initial pulse was planned for winter 2003; however, this was not implemented due to delays in establishing bait stations caused by inclement weather.

Initial knockdown

Bait-take was higher in pulse 2 than in pulse 1, 4 and 5 ($F_{4, 33}$ = 7.82, p = >0.001). Bait-take has declined steadily since pulse 2, the significant difference between pulse 2 (summer 2003) and pulse 5 (summer 2004) is encouraging (Figure 12).

As a crude comparison, the mean daily percentage bait-take for the previous perimeter baiting program was higher ($\bar{x}$ 4.4, SD 2.0, 95% CL 3.9 – 4.9) than has been recorded during the five pulses of the new program. This comparison needs to be interpreted with caution, as the two programs are quite different in the spatial layout and the number of baits laid.

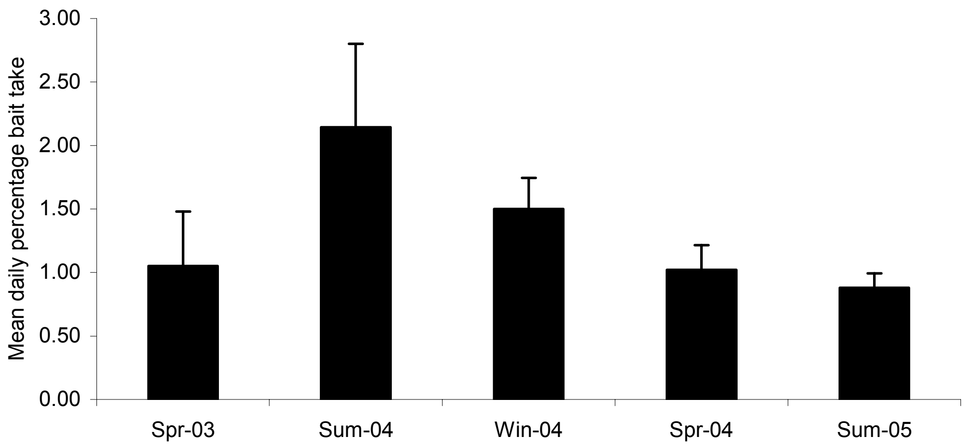

Figure 12. Mean percentage daily bait-take, Pulse 1 to 4, Grampians National Park. Bars are standard deviation. Pulse 1 Spring Oct-Dec-03, Pulse 2 Summer Jan-Mar-04, Pulse 3 Winter Jul-Sep-04, Pulse 4 Spring Oct-Dec-04, Pulse 5 Summer Jan-Mar-05.

Activity monitoring

Of the 16 sand plots transects established in the Grampians, 7 are wholly located inside the new baited area (including the old Red Rock area), 4 are on the boundary of the baited and unbaited area, and 5 are located outside the baited area.

The initial monitoring session for the newly designed sand-plot-monitoring program was undertaken in December 2003, but coincides approximately with the summer 2003 baiting pulse (Figure 13).

The proportion of sand plots with fox sign in the five pulses of the new program are shown in Figure 17. While there is no significant difference between baited and unbaited areas, there is an emerging trend that suggests that activity may be diverging among the baited and unbaited areas, with slightly higher activity in the unbaited area. Increasing the number of sand plots outside and inside the baited area would increase our capacity to detect a difference, if one actually exists.

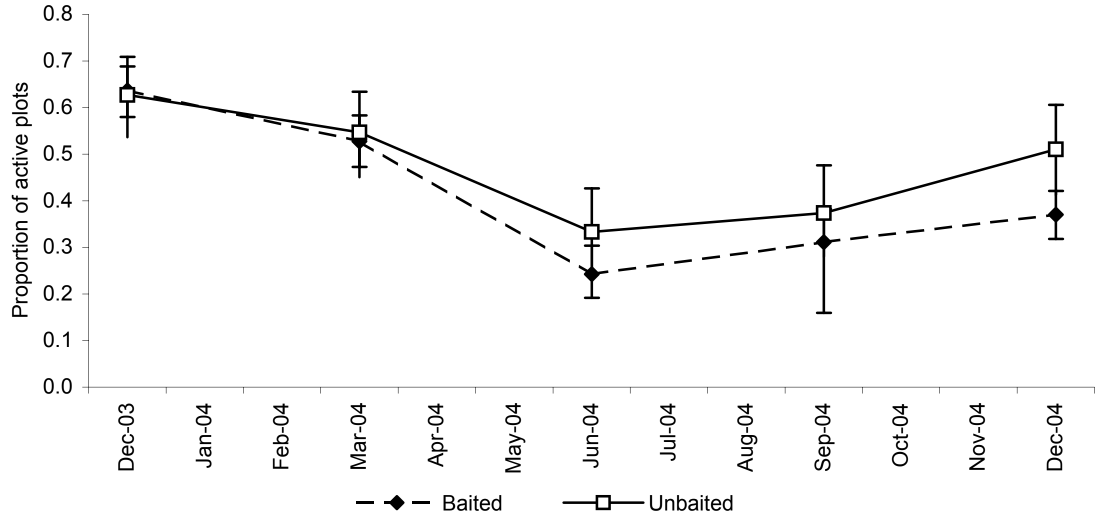

Figure 13. Proportion of sand plots with fox sign for the five pulses of the new baiting regime at the Grampians National Park. Bars are 95% confidence limits.

Wilsons Promontory National Park

Bait-take

The Wilsons Promontory baiting program differs from the Grampians in that three different intensities of baiting are applied in different areas of the park, there are 4 pulses per year and the program has been in place since April 2001.

Initial knockdown

Analysis undertaken in 03/04 (see Robley and Wright 2004) revealed that the degree in variation in bait take at each of the three nominal treatment areas was such that no difference could be detected. In 03/04 and this year we combined the three areas and averaged the percentage daily bait-take to look at the overall trend (Figure 14). Bait-take declined steeply from April 2001, the period of the first pulse, to November 2001, the period of the third pulse, and has remained relatively constant and below that of August 2001. The non-overlapping confidence limits strongly suggest that the pulsed program is effective in reducing fox activity as measured by bait-take, and that following the initial decline in bait-take, a lower level of bait-take has been maintained.

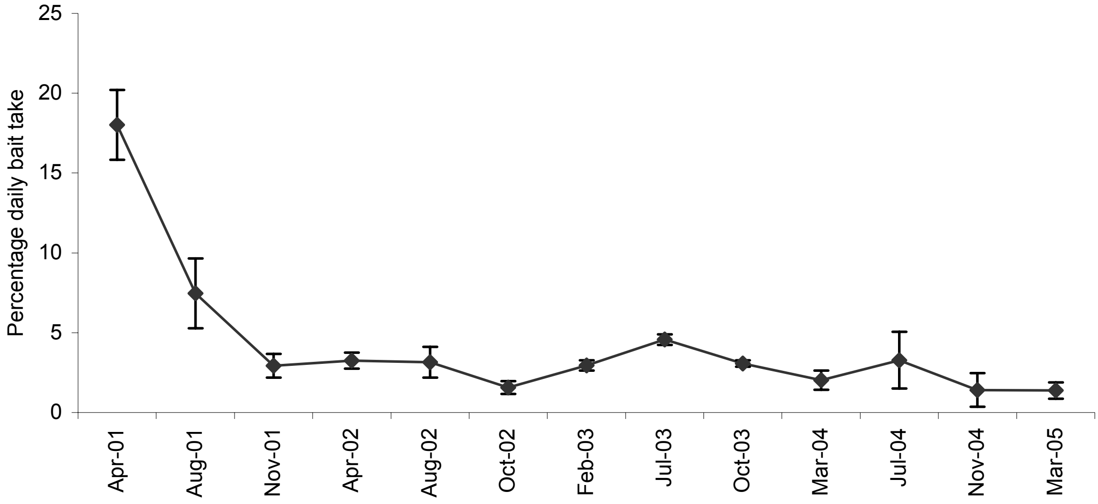

Figure 14. Overall percentage daily bait-take per pulse at Wilsons Promontory National Park. Bars are 95% confidence limits.

Activity monitoring

Activity monitoring was not implemented until the beginning of the fourth poison baiting pulse (April 2002). This was due to delays in getting the sand required for construction of sand plots certified weed and fungus free, weather, staff rostering and budgets.

This restricts our capacity to investigate the broad effect of the fox control program on fox activity levels, as by the time activity monitoring had been put in place, fox abundance had declined, as suggested by the rapid decline in bait-take (Figure 14). Instead, we look at activity levels pre- and post-baiting pulse on each of the three treatments (Figure 15a-c).

There is no detectable difference in the proportion of active plots before or after baiting in each pulse, nor is there a detectable difference through time. This is not unexpected, as bait-take has remained low relative to the initial two pulses in April- and August 2001.

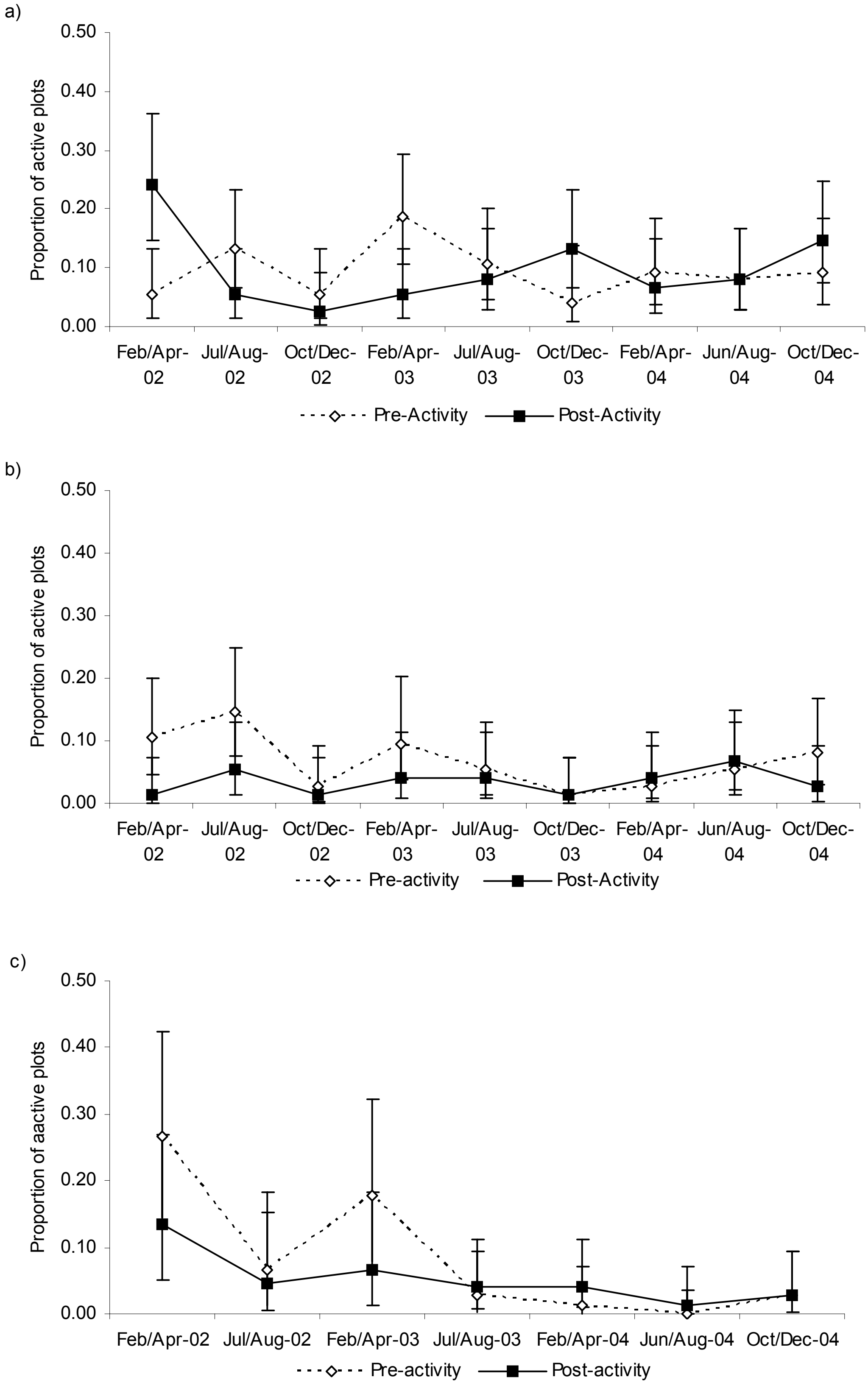

Figure 15. Fox Activity at Wilsons Promontory National Park. a) Isthmus, b) Central, c) South West. Bars are Standard Deviations.

Prey Species Monitoring

Hattah-Kulkyne National Park

In 2004-05 two sessions of prey species monitoring were undertaken in late-spring/ early-summer.

Thirty-two species from nine groups were captured over the two seven night pitfall-trapping sessions (Appendix 1). In the treated area, 21 species from seven of the groups were captured and in the non-treated area 27 species from all nine groups were captured (Appendix 1).

In 2004-05, capture rates varied among species and sites. Seventeen species were captured at both sites, with eight of these species trapped more frequently at the baited site and nine captured more frequently at the non-baited site. Four species were captured only at the baited and ten species were captured only at the unbaited site. However, to examine the effectiveness of fox control in increasing the prey population, temporal differences in capture rates between the baited and unbaited area need to be examined. At this stage, no difference in temporal trends in capture rate is evident among the baited and unbaited area (Figure 16).

Capture results for the nine groups of animal surveyed are variable among both years and sites. Amphibians have not been recorded in the two years on the treated site, but have in both years on the non-treated site. Blind snakes were not recorded in the first year, but were in the second and on both the treated and non-treated sites at the same rate. Capture rates for Dragons were higher in the second year on the treated and non-treated site. Capture rates for Geckos decline on both sites, but more so on the non-treated site. There was little detectable difference in capture-rates on the treated and non-treated site between years for lizards and mammals. Skinks declined on both sites, but more so on the treated site. Snakes declined on the treated site, but increased on the non-treated site.

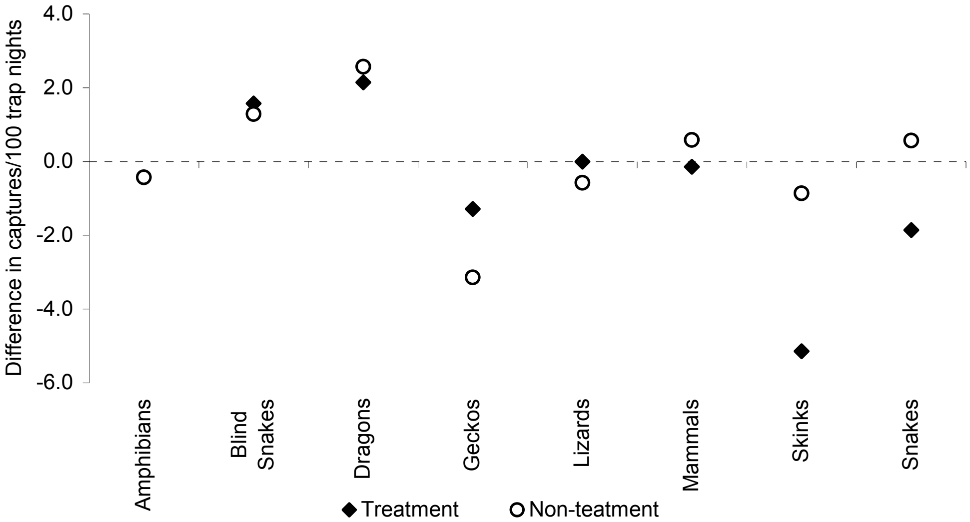

Figure 16. Differences in capture rates between 04/05 and 03/04 at Hattah-Kulkyne National Park. Trap success = captures/100 trap nights. Amphibians were captured only on the non-treatment site.

Coopracambra National Park

Prey-species monitoring was undertaken in August and September 2004. Nine mammal species were captured over the two trapping sessions, four of which were the target species, i.e., Southern Brown Bandicoot (*Isoodon obesulus*), Long-nosed Bandicoot (*Perameles nasuta*) and Long-nosed Potoroo (*Potorous tridactylus)* and the Common Brush-tailed Possum *(Trichosurus vulpecula).* We also recorded Bush Rat (*Rattus fuscipes*), Swamp Rat (*Rattus lutreolus*), Suagr Glider (*Petaurus breviceps*), Ringtailed Possum (*Pseudocheirus peregrinus*) and European Rabbit (*Oryctolagus cuniculis*).

We compared the estimated number of individuals for the three target species from across all 7 sampling sites between years (Figure 17). The overlapping 95% confidence limits indicate that, while estimated abundance for long-nosed potoroos and long-nosed bandicoots has increased it is not a statistically-significant increase. Confidence limits for estimates of abundance of Southern brown bandicoots do not overlap, suggesting there may have been an increase in abundance, although it is too early to attribute this increase to the effects of fox control.

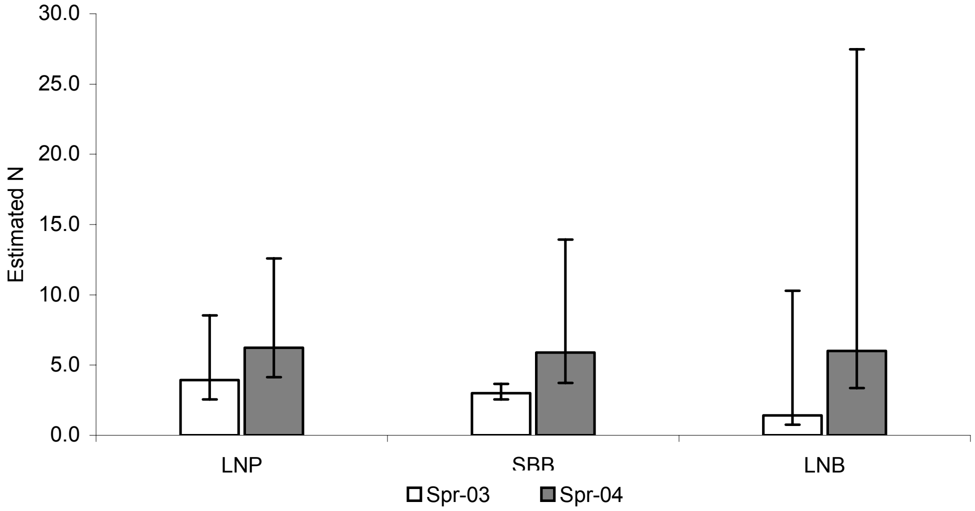

Figure 17. Estimated number of long-nosed potoroos. Bars are 95% confidence limits.

Little Desert National Park

Prey-species monitoring was undertaken October and November 2004. Overall 24 species were captured with a total of 651 captures. In the Eastern Block 20 species from 7 groups were captured over the 7 nights of pitfall trapping, in the Central Block 15 species from 6 groups, and in the Western Block 18 species were captured (Appendix 1). By far the majority of animals captured were herptofauna. At all three sites skinks were the most common group captured, with the Obscure Skink dominating captures. Lizards and amphibians, including the Spade-foot Toad and the Lined Worm-lizard, were the next most commonly captured group.

Only 4 species of mammal were captured across all three sites. These were the Western Pygmy Possum, Common Dunnart (Vulnerable in Victoria), Silky Mouse and the introduced House Mouse. Of the native mammal species captured, silky mice were the most common, being captured in all sessions on all sites.

There is no clear trend in prey species abundance associated with fox control treatment. The difference in capture rates between years within blocks varied among groups (Figure 18). Across all sites, capture rates for Amphibians, Dragons and Legless Lizards were lower in 2004-05 than 2003-04, while capture rates for snakes changed little. No other groups showed a consistent trend in difference in capture rate between years. For example, mammal captures were higher on the Eastern Block in 2004-05 than in 2003-04, while on the Central and Western Block they tended to be lower. The reason for these differences is unclear but could be attributed to variations in temperature or habitat.

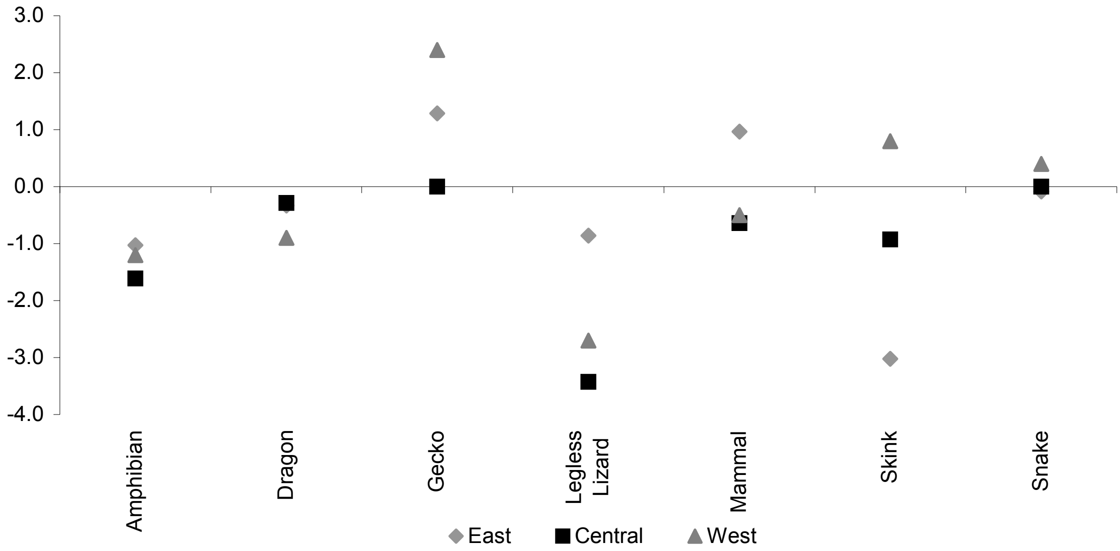

Figure 18. Differences in capture rates at Little Desert National Park between 03/04 and 04/05.

Eumeralla Coastal Reserve (Codrington)

Nest fate and hatching success

Between November 2004 and March 2005, 72 Hooded Plover nests were detected. Of these nests, 11 (or 15.3%) hatched successfully. The cause of failure was determined for 43 of the 61 nests that failed (59.7% of all nests, 70% of nests that failed) (Table 4). These results are generally consistent with those reported by Ressom (2004) in the same survey area between November 2003 and March 2004. That survey found that of 56 nests detected, 9 (16.1%) hatched successfully, while the cause of nest failure was determined for 26 nests (46.4% of all nests, 60.5% of nests that failed).

Of particular interest in the current survey (2004-05), was the relatively high number of nest failures (34.4%; n = 21) due to flooding of nesting habitat.

Overall, hatching success observed in 2004-05 approximates that reported for other areas of the Victorian coast (Weston & Morrow 2000). On the Codrington coast, hatching success reported for the three surveys with sufficient data (2000-01; n = 22, 2003-04; n = 56, 2004-05; n = 72) was 21.4%, 23.08% and 20.4% respectively (of all nests where the fate was determined i.e. hatching confirmed or cause of failure known).

Table 4. Nest fates recorded during the 2004-05 survey.

Fate	Cause	Number of nests	Percentage of nests	Percentage of nest failures
Successful	Hatched	11	15.28	
Failed	Fox	9	12.50	14.75
Failed	Silver Gull	4	5.56	6.56
Failed	Flooding	21	29.17	34.43
Failed	Dog	2	2.78	3.28
Failed	Raven	2	2.78	3.28
Failed	Abandoned	5	6.94	8.20
Failed	Unknown	18	25.00	29.51
Total		**72**	**100.00**	**100.00**

Grampians National Park

Prey-species monitoring was undertaken in October and November 2004. Overall we had 365 captures of seven species of mammals (Appendix 1). Of these, four were the target species Southern Brown Bandicoot (9 captures: 3 female, 4 male, 2 not determined), Long-nosed Potoroo (3 captures, 1 female, 2 male), Common Brush-tailed Possum (30 captures: 4 female, 7 males, 19 not determined) and Heath Mouse (107 captures, 20 females, 16 males, 71 not determined). Pouch young were recorded for Long-nosed Potoroo, Southern Brown Bandicoot and Common Brush-tailed Possum. There were also 16 captures of Western Pygmy Possum. Of all species captured, no differences in capture rates between 2003 and 2004 were detected for any species except Common Brush-tailed Possum (Figure 19).

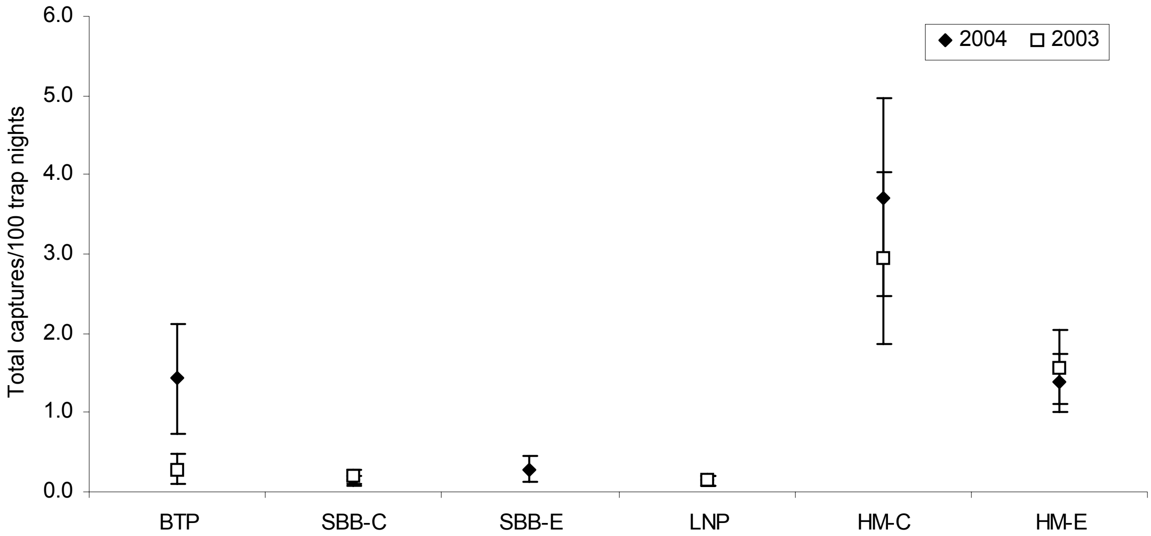

Figure 19. Prey Species Response at Grampians National Park. SBB – Southern Brown Bandicoot (c-cage, E-Elliott), LNP – Long-nosed Potoroo, BTP – Brush-tailed Possum, HM – Heath Mouse. Bars are 95% confidence limits.

Wilsons Promontory National Park

In 2003 it was planned to survey 7 trapping sites for the presence of three target species, as was done for Coopracambra and the Grampians. Unfortunately, only 4 sites were established in time to undertake surveys. Despite this set back, two of the three target species were captured during the spring 2003 trapping session. These species were Long-nosed Bandicoot (5 captures, 2 females and 1 male) and Long-nosed Potoroo (48 captures, 4 females, 9 males).

In 2004 all 7 trapping sites were surveyed in October and November 2004. This extra effort resulted in two additional target species being encountered. These were the Southern Brown Bandicoot and Common Brush-tailed Possum.

In 2003 long-nosed potoroos were captured at Black Gully, St Kilda Junction, Vereker Track and Telegraph Track, in 2004 they were captured at these sites and Roaring Meg. Only 1 male was captured at this site. We estimated abundance in 2003 and 2004 excluding the Roaring Meg site (Figure 20). The non-overlapping 95% confidence limits suggest that there has been an increase in Potoroos between 2003 and 2004.

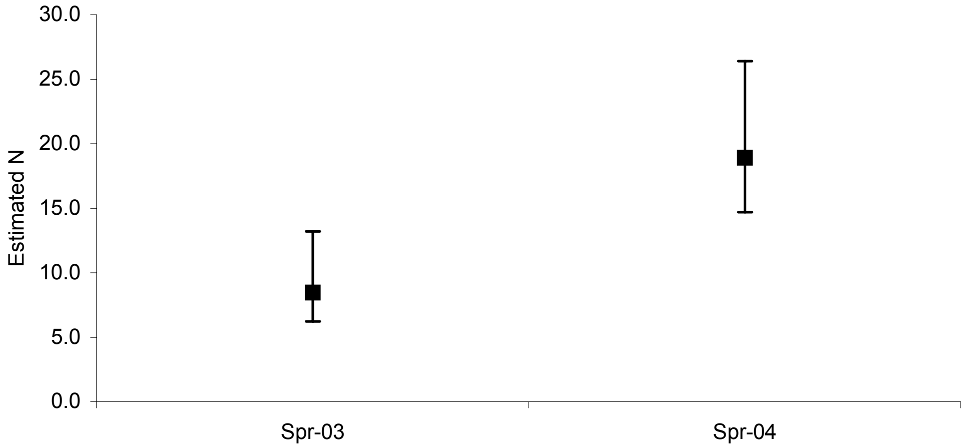

Figure 20. Estimated abundance for Long-nosed Potoroo at Wilsons Promontory National Park.

Long-nosed bandicoots were only captured at Sealers Cove, thus were not able to estimate 95% confidence intervals around trap success. Due to the low numbers captured, we were restricted to estimating captures/100 trap nights for long-nosed bandicoots. This standardises the total number of animals captured by effort (Figure 21).

Southern brown bandicoots were captured only during session one, two males were captured at Vereker Track and one at St Kilda Junction.

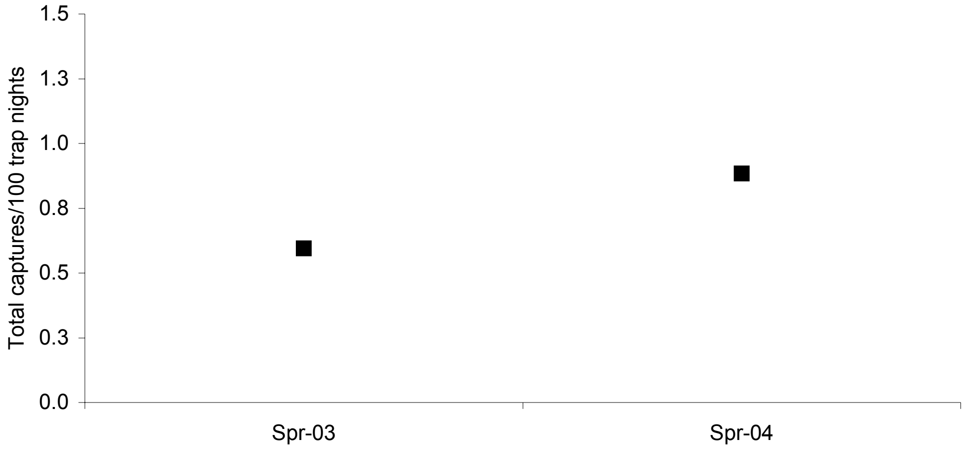

Figure 21. Trap Success for Long-nosed Bandicoot at Wilsons Promontory National Park. Trap success = total captures/100 trap nights.

DISCUSSION

There are two equally important outcomes anticipated for the Fox AEM project. The first is a greater understanding of the efficiency of the differing fox control strategies (including costs) and the second is a better understanding of the response by native mammal species to these strategies. It is still too early to present information on the cost/benefits of the various control strategies as some programs (eg. Grampians) are relatively new and it will take some time to determine how these strategies impact on levels of bait-take and fox activity. However, results do indicate some differences in effectiveness among control strategies. In particular, differences are emerging in the extent to which some strategies reduce fox activity. Additionally, whilst a detailed analysis of costs and benefits of each strategy is not yet possible, issues relating to the ongoing implementation of the Fox AEM program and implications for fox control more broadly have been identified.

Effectiveness of the various fox control strategies

The annual report for the Fox AEM project for 2003-04 identified that the two annual poison baiting programs (Coopracambra and Hattah-Kulkyne National Parks) both appear to have been effective in reducing fox activity (Robley and Wright 2004). Graphical analysis of all bait-take data collected to date indicates that this reduction in activity has been maintained over 2004-05. However, for both of these sites, the relatively short periods of free-feeding resulted in high degrees of variation in the free-feed bait take. This has led to overlapping confidence limits between the free-feed and the poison baiting periods. The outcome is that statistically there is no significant difference between the two periods.

While both continuous annual programs have shown sustained reduction in fox activity, the proportion of bait-take at Coopracambra and Hattah-Kulkyne National Parks are very different. This may be a result of a difference in underlying fox density and the landscape surrounding these two parks. These differences may in turn have an influence on the intensity of baiting required to manage fox populations. Coopracambra National Park is heavily dissected by rugged mountainous terrain dominated by moist and dry foothill forest. The park is surrounded by national park on the NSW border and State Forest in Victoria. Hattah-Kulkyne National Park is moderately undulating dominated by Mallee and Riverine Grassy Woodlands and is surrounded by agricultural enterprises. The relatively low-intensity baiting applied at Coopracambra National Park may not have been successful if the underlying densities were higher. Knowledge of the underlying densities may influence the design of future baiting programs. The Fox AEM project offers logistical and infrastructure support for the development of sampling techniques to assess fox density. This could be offered as in-kind support for further investigations.

A similar picture of sustained reduction in bait take is emerging from the pulsed program at Wilsons Promontory National Park. Overall, bait-take has declined since the beginning of the poisoning program. However, while three spatial intensities of baiting are used at Wilsons Promontory National Park, there was no detectable difference in the rate of change in bait-take between the Isthmus, Central and South-west baiting programs. The three treatment areas may not be independent. The Isthmus and South-west areas both abut the Central area and hence, are not isolated geographically. Consequently, baiting in one area may impact on foxes across the other areas.

Sand plot monitoring was established to provide a measure of fox activity independent of bait-take. Unfortunately, sand plot activity results can not be used to assist in examining any differences among the three spatial intensity treatments, as this monitoring did not begin until after the initial decline in bait-take had occurred.

The relative level of bait-take at Wilsons Promontory National Park is much higher than that for both Hattah-Kulkyne and Coopracambra National Parks. It is not possible to determine the causes of this difference at present. As discussed above, the landscape context of a particular park may influence fox density. However, other factors such as the reliability of food supply, climate and local habitat complexity may also be important.

Since the commencement of the pulsed baiting program at the Grampians National Park, five baiting pulses have been completed. Initial results are encouraging, with an overall decline observed since the second baiting pulse in summer 2004. While it is too early to draw any firm conclusions about the effectiveness of this program, the impact on fox activity seem to be consistent with those observed for the pulsed program at Wilsons Promontory National Park.

In contrast to the reduction in bait-take observed at the parks undertaking annual and pulsed programs, the two seasonal programs do not appear to be reducing or maintaining a reduced level of bait-take. At Little Desert National Park, bait-take remains unchanged within a season and from year to year. Similarly, although the landscape context of Eumeralla Coastal Reserve is different to that of Little Desert, the pattern of bait-take in this seasonal program is similar. There was no discernible decline in bait-take or activity recorded and while fox predation was identified as one cause of Hooded Plover nest failure, it was not possible to determine if the control program was effective in reducing this impact.

While it will take some time to build a sound understanding of the costs and benefits of each of the strategies being examined, some trends seem to be emerging. In particular, continuous annual and pulsed programs seem to bring about a sustained reduction in fox activity whereas no such reduction has been observed for seasonal programs. The potential implications of these results need to be considered in developing future fox control programs. For example, the value of initiating a seasonal program may be limited if long-term suppression of foxes is a goal of that program. However, all of the reasons for undertaking the control program, the nature of the species that the program is intended to protect and other factors such as the capacity to deliver the program also need to be considered. Furthermore, whilst differences do appear to be emerging in the ability of some treatments to reduce fox activity, we do not yet have a clear understanding of whether any of the treatments being examined will actually result in an increase in the target prey-species. At all sites, including those with a demonstrable reduction in bait-take, there remains a constant residual level of bait-take. It is not known if this is due to dispersing or immigrating foxes or a combination of both. What is clear however, is that even high intensity continuous programs are unable to remove all foxes for even a short period of time. This reinforces the need to apply constant pressure on the fox population to maintain a reduced level of density. Knowledge of the timing, source and sex of these animals may provide information, enabling managers to better design fox control programs. The Fox AEM project can provide logistical and infrastructure to support research into this area.

Change in bait type

In May 2004, the type of bait used at Hattah-Kulkyne National Park was changed from deep fried liver to FoxOff™ due to the Department of Primary Industries enforcement of standing policy and no longer supplying the liver bait. There was a significant increase in the proportion of daily bait take between the period of liver baiting and the period of FoxOff™ baiting. Temporal variation in underlying food supply or fox density may explain some of the difference, as would an inherent difference in detectability, palatability, or longevity, of the different bait types. The implication of this needs further investigation as the possible effectiveness of future baiting programs could be compromised

Sand Plot Activity Monitoring

The use of sand plot activity monitoring was instigated to provide an independent measure of change in the fox population in an attempt to overcome the perceived short falls in using bait take as a measure of success. Bait could be taken and cached, or taken by other species leading in a biased interpretation of take. A concurrent change in activity would provide supporting evidence that there had in fact been a change in the fox population.

The level of variation recorded in the sand plot data is such that only a very large effect size could be detected with any confidence. This means that at present, sand plot data do not provide a level of sensitivity that can support the trends evident in bait take data. Consequently, on the basis of sand plot data we are unable to state with any confidence that there has been a change in the fox population at any site.

There are three possible solutions to this dilemma. First, an investment could be made into further analysing the data. Using a Bayesian approach to analysing the data may provide us with the ability to assign probability statements to changes in activity. That is, it might be possible to state that there is a 70% chance that fox activity has in fact declined, whereas standard statistical analysis would state that there was no significant difference. This analysis would take advantage of the effort and investment already made in the project.

A second approach might be to increase the effort of the sand plot monitoring to account for the observed degree of variation. The principles of sampling design dictate that the precision of an estimate is generally related to the number of samples to be collected. However; the number of samples collected is usually tempered by the practicalities associated with budgets and available resources. It may be that these constraints result in a level of sampling effort that is not sufficient to account for the various sources of error associated with data collection, i.e. process and measurement error. Increasing the number of plots from 25 to 40 per treatment is likely to provide a robust estimate of activity. However, given that control programs have been in place for some time, this new effort could only be used to trigger changes in control effort in response to a significant increase in fox activity.

The third option is to discontinue the use of sand plot monitoring and redirect the resources currently allocated to that activity to other areas of the AEM program. However, before discontinuing sand pad monitoring, there would be value in exploring the potential of a Bayesian approach as identified above.

Prey Species Monitoring

Prey-species monitoring was successfully implemented in all parks. At this stage, target species have been recorded in all parks, however they have been encountered in very low numbers, and not at all trapping locations.

These results are encouraging, as the effort being expended on prey species monitoring appears to be sufficient to detect those species that we are most interested in. In addition, while the initial sampling indicates low abundances, this is consistent with our expectations that foxes are suppressing prey populations. It is hoped that if baiting reduces fox populations, we will see a shift in abundance and/or site occupancy by prey species. However, while bait-take and sand pad results are suggesting differences between seasonal and annual baiting programs, it will be a number of years before we can expect to see any changes in prey species abundance or differences in prey species responses among sites.

Issues

While we made every attempt to include the critical components of experimental design in this AEM project, it was not possible to randomise treatments, collect pre-treatment prey species monitoring data, replicate most of the treatments or establish control sites. This places some limitations on the universality of the results and will limit the robustness of the inferences that can be made.

Accounting for additional sources of variation may increase the reliability of the outcomes. These include:

- *measuring the structural complexity of the monitoring locations within each site*
- *recording previous management histories, eg. time since last fire*
- *measuring temperature, rainfall, soil type and general floristic composition of each monitoring site.*

The variability that these factors contribute to the prey-species response can be accounted for in future analysis and aid in the interpretation of observed patterns in prey species response.

Changes to the programs at any of the sites involved in the Fox AEM project should be considered in the context of the overall Fox AEM project. One consequence of the AEM approach is that some management strategies may be found to be more effective than others. As managers become more aware that they are managing in an apparent sub-optimal manner they will naturally wish to alter their approach. However, changing the management strategy at sites too early will affect the capacity of this project to provide a solid understanding of the differences in the effectiveness of different management strategies. It is recognised however, that regardless of the implications for the overall project, managers may still change the approach being taken at a site.

Effective delivery of the program relies on consistent delivery of fox control and monitoring in accordance with the design of the project. Inconsistent baiting effort results in greater variation in bait-take and greater difficulty in interpreting any patterns, which for example, has been the case for Hattah-Kulkyne National Park.

It is also important to recognise that where components of the project such as baiting or sand plot monitoring are out-sourced, the contractors need to be well-supervised and experienced and must as comply with the methods used in this project.

Future Programs

Eummeralla Coastal Reserve

The reserve was included in the program in 2003 in an attempt to overcome the difficulties in baiting and monitoring encountered at Discovery Bay National Park. Unfortunately, despite the considerable effort that has gone into baiting, sand plot monitoring and shooting outside the reserve, similar issues have arisen at Eummeralla. Suppression of foxes in a small linear reserve presents problems with rapid migration, associated with a large boundary to area ratio. Other potential critical factors, eg predation by gulls and ravens, nest destruction by pets and human disturbance, also influence nestling survival and can not be easily separated out from predation by foxes. As a result, this reserve will no longer be included as part of the Fox AEM project.

Little Desert National Park

The results of the baiting program indicate that seasonal baiting is unlikely to be effective at reducing fox populations for prolonged periods. It is thought that this is required to allow certain native species (particularly mammals) to respond and maintain viable populations. Strict adherence to an AEM approach requires all experimental treatments established at the outset of the program would be maintained for the duration of the experiment. However, given the clear lack of suppression in fox activity at Little Desert National Park and the fact that the design of the experiment has already been modified at other sites, Parks Victoria felt that maintaining such a management strategy was not desirable. It was decided therefore to alter this program by changing to either a pulsed or continuous annual program on the one of the blocks currently-baited and to maintain the seasonal program on the other baited block. The nature of these changes is yet to be determined.

Retaining one block as a seasonal program and one as a non-treatment area will provide a baseline against which to compare the new program. As the annual program is essentially starting a new program, it would be expected that a coherent native species response to the new annual program would take up 5 years to detect.

Concluding remarks

The Fox AEM project is progressing and while trends in the effectiveness of some baiting strategies are emerging, new issues such as the landscape context and the composition of the residual fox populations and the relationship between indices and actual changes in abundance are also emerging. Prey species monitoring has produced interesting results, such as the increase in southern brown bandicoots at Coopracambra and long-nosed potoroos at Wilsons Promontory but, as was originally noted, it will take a number of years to provide a robust indication of the effectiveness of the different control strategies.

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REFERENCES

Allen, L., Engeman, R., and Krupa, H. (1996). Evaluation of three relative abundance indices for assessing dingo populations. *Wildlife Research* **23**,197 – 206.

Allen, L., Engeman, R., Baker, N., and Gonzalez, T. (2003). The development, utility and current applications of a passive activity index for monitoring wild dogs and other wildlife in Australia. Proceedings and Abstracts 3rd International Wildlife Management Congress. Christchurch, New Zealand. Pp 162.

Bamford (1970). Evaluating opossum poisoning operations by interference with non-toxic baits. *Proceedings of the New Zealand Ecological Society* **17**, 118-25.

Choquneot, D., and Robley, A. (2001a). Proceeding of a workshop on Adaptive Experimental Management of Fox Control for Parks Victoria 1. Optimising fox control through adaptive experimental management. Held on 13 July 2001 Brimbank Park, Melbourne. Department of Natural Resources and Environment.

Choquneot, D., and Robley, A. (2001b). Proceeding of a workshop on Adaptive Experimental Management of Fox Control for Parks Victoria 2. Study sites and design of the Adaptive Experimental Management project. Held on 13th August at Bairnsadale and 15th August at Horsham 2001. Department of Natural Resources and Environment.

Mahon, P. S., Banks, P. B., and Dickman, C. R. (1998). Population indices for wild carnivores: a critical study in sand-dune habitat, south-western Queensland. *Wildlife Research* **25**,11-22.

Murray, A., and Poore, R. (2002). Project Deliverance: the response of critical-weight range mammals to effective fox control in mesic forest habitats in Far East Gippsland, Victoria. Annual Report 2001. Flora and Fauna Unit, Department of Sustainability and Environment Gippsland Region.

Murray, A., and Poore, R. (2004). Project Deliverance: the response of critical-weight range mammals to effective fox control in mesic forest habitats in Far East Gippsland, Victoria. Draft Final Report 2004. Flora and Fauna Unit, Department of Sustainability and Environment Gippsland Region.

Ressom, R. 2001. Monitoring Hooded Plovers on the Codrington Coast, Western Victoria. Report to Parks Victoria, Portland.

Ressom, R. 2002. Monitoring Hooded Plovers on the Codrington Coast, Western Victoria. Report to Parks Victoria, Portland.

Robley, A. and Choquenot, D. (2002) Assessing the alignment of Parks Victoria's fox control program with priorities for reducing risks to native species. Arthur Rylah Research Institute. Report to Parks Victoria.

Robley, A., Einoder, L., Potts, J., Scroggie, M., and Silins, J. (2004). The effectiveness of a large-scale fox control operation in South-eastern Australia: assessing changes in predator activity and detection rates of medium-sized mammals. (Arthur Rylah Research Institute, Department of Sustainability and Environment: Melbourne).

Robley, A, and Wright, J (2003). Adaptive Experimental Management of Foxes. Annual Report for Year 2, July 2002 – June 2003. Parks Victoria Technical Series. Parks Victoria, Melbourne.

Rowlands R. P. V. (1999) *New Zealand Geckos, a Guide to Captive Maintenance and Breeding*, 3rd rev. edn. EcoPrint, Auckland, New Zealand.

Saunders, G., B. Kay and L. McLeod (1999). Caching of baits by foxes (*Vulpes vulpes*) on agricultural lands. *Wildlife Research* **26**, 335 - 340.

Saunders, G., Coman, B., Kinnear, J., and Braysher, M. (1995). Managing Vertebrate Pests: Foxes. Australian Government Publishing Services, Canberra.

Sit, V., and Taylor, B. (1998). *Statistical methods for adaptive management studies*. British Colombia Ministry of Forests, Land Management Handbook **42**.

Thomson, P. C., and Kok, N. E. (2002). The fate of dried meat baits laid for fox control: the effects of bait presentation on take by foxes and non-target species, and on caching by foxes *Wildlife Research* **29**, 371-377.

van Polanen Petel, A. M., Marks, C. A., and Morgan, D. G. (2001). Bait palatability influences the caching behaviour of the red fox (*Vulpes vulpes*). *Wildlife Research* **28**, 395-401.

Walters C. (1997). Adaptive Management of Renewable Resources. MacMillan Publishing Company: New York.

Weston, M. A. and Morrow, F. (2000). Managing Hooded Plovers in Western Victoria. Report to Parks Victoria, Portland.

Weston, M. A. (2001). Evaluation of existing information and information needs for the management of Hooded Plovers on land managed by Parks Victoria. Parks Victoria, Melbourne.

Zar, J. H. (1999). Biostatistical Analysis. (Prentice Hall: New Jersey).

APPENDICES

Species Captured in Prey-Species Monitoring.

Table A1.1. Species captured and trap success at the fox control (treated) and no fox control (non-treated) sites, Hattah-Kulkyne National Park in December 2004

Trap success = captures / 100 trap nights,. The herptofauna groups are based on Agamids (dragon) Gekkonids (geckos) Pygopodids (lizards) Scincids (skinks) and snakes (families have been grouped into one class).

			Trap success	
Group	**Scientific Name**	**Common Name**	**Treated**	**Non-Treated**
Geckos	*Christinus marmoratus*	Marbled Gecko	0.14	
Geckos	*Diplodactylus intermedius*	Southern Spiny-tailed Gecko	0.14	0.57
Geckos	*Diplodactylus tessellates*	Tessellated Gecko		0.57
Geckos	*Diplodactylus vittatus*	Wood Gecko	0.43	0.14
Geckos	*Lucaseum damaeum*	Beaded Gecko	2.29	1.86
Pygopids	*Apraisia inaurita*	Pink Nosed Worm-lizard	0.14	0.00
Pygopids	*Delma australis*	Southern Legless Lizard		0.14
Pygopids	*Delma butleri*	Butler's Legless Lizard		0.14
Pygopids	*Lialis burtonis*	Burton's Snake-Lizard	0.29	0.14
Dragons	*Amphibolurus nobbi*	Nobbi Dragon	1.57	1.29
Dragons	*Ctenophorus fordi*	Mallee Dragon	1.57	4.57
Dragons	*Pogona vitticeps*	Central Bearded Dragon	0.43	0.14
Dragons	*Varanus gouldii*	Sand Goanna	0.14	
Skinks	*Cryptoblepharus carnabyi*	Wall Skink		0.14
Skinks	*Ctenotus brachyonyx*	Murray Striped Skink	1.00	0.86
Skinks	*Ctenotus brooksi*	Brooks' Skink		0.14
Skinks	*Ctenotus regius*	Regal Striped Skink	0.71	3.14
Skinks	*Egernia inornata*	Desert Skink	0.14	0.43
Skinks	*Lerista bougainvillii*	Bougainville's Skink		0.29
Skinks	*Lerista punctattovittata*	Spotted Burrowing Skink	0.14	0.86
Skinks	*Menetia greyii*	Grey's Skink	0.14	0.43
Skinks	*Morethia boulengeri*	Boulenger's Skink	0.57	1.43
Skinks	*Tiliqua occipital*is	Western Blue-tongue	0.14	
Blind Snakes	*Ramphotyphlops australis*	Southern Blind Snake	0.14	0.14
Blind Snakes	*Ramphotyphlops bituberculatus*	Peter's Blind Snake	1.43	1.14
Elapids	*Pseudonaja textiles*	Eastern Brown Snake		0.29
Elapids	*Simoselaps australi*s	Coral Snake	0.14	
Elapids	*Suta nigriceps*	Mitchell's Short-tailed Snake		0.29
Amphibians	*Limnodynastes dumerillii*	Eastern Banjo Frog		0.14
Mammals	*Cercatetus lepidus*	Little Pygmy Possum		0.14
Mammals	*Mus musculus*	House Mouse	0.86	0.57
Mammals	*Ningaui yvonneae*	Mallee Ningaui		0.14

Table A1.2. Species captured at Coopracambra National Park in 2003/4 and 2004/5.

We estimated N for the three key species in each year. See figures in text for 95% confidence limits.

			Trap success	
Group	**Scientific Name**	**Common Name**	**03/04**	**04/05**
Mammal	*Trichosurus vulpecula*	Common Brush-tailed Possum	-	-
Mammal	*Potorous tridactylus*	Long-nosed Potoroo	4	6
Mammal	*Perameles nasuta*	Long-nosed Bandicoot	2	6
Mammal	*Isoodon obesulus*	Southern Brown Bandicoot	3	6
Mammal	*Rattus lutreolus*	Swamp Rat	-	-
Mammal	*Rattus fuscipes*	Bush Rat	-	-
Mammal	*Oryctolagus cuniculis*	European Rabbit	-	-
Mammal	*Petaurus breviceps*	Sugar Glider	-	-
Mammal	*Pseudocheirus peregrinus*	Ringtail Possum	-	-

Table A1.3. Species captured at the Eastern Block, Little Desert National Park in 2003/4 and 2004/5.

The herptofauna groups are based on Agamids (dragon) Gekkonids (geckos) Pygopodids (lizards) Scincids (skinks) and snakes (families have been grouped into one class).

			Trap success	
Group Name	**Scientific name**	**Common Name**	**03/04**	**04/05**
Amphibian	*Ctenophorus pictus*	Painted Dragon	1.14	1.43
Amphibian	*Pseudophryne bibronii*	Brown Toadlet	-	0.57
Amphibian	*Neobatrachus sp.*	Spade-foot Toad	1.43	0.29
Dragon	*Amphibolurus norrisi*	Mallee Tree Dragon	0.86	0.57
Gecko	*Christinus marmoratus*	Marbled Gecko	2.86	0.57
Legless Lizard	*Aprasia striolata*	Lined worm-lizard	0.29	-
Mammal	*Cercartetus concinnus*	Western Pygmy Possum	0.86	2.57
Mammal	*Mus musculus*	House Mouse	0.86	0.29
Mammal	*Pseudomys apodemoides*	Silky mouse	6.86	0.57
Mammal	*Sminthopsis crassicaudata*	Fat-tailed Dunnart	0.86	-
Skink	*Cryptoblepharus carnabyi*	Skink	-	0.29
Skink	*Lamprophpholis delicata*	Garden Skink	0.29	0.86
Skink	*Lerista bougainvilli*	Skink	0.29	-
Skink	*Morethia obscura*	Skink	3.43	6.29
Snake	*Diplodactylus vittatus*	Eastern Stone Gecko	0.29	-
Snake	*Echiopsis curta*	Bardick	0.29	-
Snake	*Pseudonaja textiles*	Common Brown Snake	0.29	-
Snake	*Ramphotyphlops australis*	Southern Blind Snake	-	0.29
Snake	*Suta nigriceps*	Snake	1.14	0.29

Table A1.4. Species captured at the Central Block, Little Desert National Park in 2003/4 and 2004/5. The herptofauna groups are based on Agamids (dragon) Gekkonids (geckos) Pygopodids (lizards) Scincids (skinks) and snakes (families have been grouped into one class).

			Trap success	
Group	**Scientific Name**	**Common Name**	**03/04**	**04/05**
Amphibian	*Limnodynastes dumerilli*	Banjo Frog	0.57	1.71
Amphibian	*Neobatrachus sp.*	Spade-foot Toad	2.00	1.14
Dragon	*Amphibolurus norrisi*	Mallee Tree Dragon	0.29	0.86
Gecko	*Christinus marmoratus*	Marbled Geko	-	0.29
Legless Lizard	*Aprasia striolata*	Lined worm-lizard	2.29	-
Legless Lizard	*Pygopus lepidopodus*	Common Scaly-foot	-	0.29
Mammal	*Cercartetus concinnus*	Western Pygmy Possum	0.90	1.43
Mammal	*Mus musculus*	House Mouse	-	0.29
Mammal	*Pseudomys apodemoides*	Silky mouse	0.29	
Skink	*Ctenotus orientalis*	Skink	0.86	0.57
Skink	*Lamprophpholis delicata*	Garden Skink	0.57	0.86
Skink	*Lerista bougainvilli*	Skink	1.14	0.86
Skink	*Morethia obscura*	Skink	4.57	15.14
Snake	*Suta nigriceps*	Snake		0.57

Table A1.5. Species captured at the Western Block, Little Desert National Park in 2003/4 and 2004/5. The herptofauna groups are based on Agamids (dragon) Gekkonids (geckos) Pygopodids (lizards) Scincids (skinks) and snakes (families have been grouped into one class).

			Trap success	
Group	**Scientific name**	**Common Name**	**03/04**	**04/05**
Amphibian	*Ctenophorus pictus*	Painted Dragon	2.86	4.29
Amphibian	*Neobatrachus sp.*	Spade-foot Toad	0.29	2.00
Dragon	*Amphibolurus norrisi*	Mallee Tree Dragon	0.86	1.43
Dragon	*Pogona barbata*	Eastern Bearded Dragon	0.29	-
Gecko	*Christinus marmoratus*	Marbled Geko	2.86	3.43
Legless Lizard	*Aprasia striolata*	lined worm-lizard	1.14	0.29
Mammal	*Cercartetus concinnus*	Western Pygmy Possum	0.57	0.86
Mammal	*Mus musculus*	House Mouse	0.57	0.57
Mammal	*Pseudomys apodemoides*	Silky mouse	2.00	4.86
Mammal	*Sminthopsis crassicaudata*	Fat-tailed Dunnart	-	0.29
Skink	*Ctenotus orientalis*	Skink	3.43	2.86
Skink	*Lamprophpholis delicata*	Garden Skink	0.29	0.29
Skink	*Lerista bougainvilli*	Skink	3.43	1.43
Skink	*Morethia obscura*	Skink	9.43	9.14
Skink	*Trachydosaurus rugosus*	Blue tongue lizard	-	0.29
Snake	*Diplodactylus vittatus*	Eastern Stone Geko	0.86	1.14
Snake	*Suta nigriceps*	Snake	-	0.57

Table A1.6. Species captured at the Grampians National Park in 2003/4 and 2004/5.

Trap success calculated for target species only.

			Trap success	
Group	**Scientific Name**	**Common Name**	**03/04**	**04/05**
Mammal	*Trichosurus vulpecula*	Common Brush-tailed Possum	0.29	1.43
Mammal	*Cercartetus nanus*	Eastern Pygmy Possum	-	-
Mammal	*Pseudomys shortridgei*	Heath Mouse	*2.95	*3.71
Mammal	*Potorous tridactylus*	Long-nosed Potoroo	0.19	0.14
Mammal	*Tachyglossus aculeatus*	Short-beaked Echidna	-	-
Mammal	*Isoodon obesulus*	Southern Brown Bandicoot	0.14	0.14
Mammal	*Antechinus agil*is	Brown Antechinus	-	-
Mammal	*Rattus lutreolus*	Swamp Rat	-	-
Lizard	*Tiliqua rugosa*	Shingleback	-	-
Lizard	*Tiliqua scincoides*	Common Blue-tongue	-	-

*trap success for cage traps only. Heath mouse were also captured in Elliott traps in 2003 (1.57) and 2004 (1.38), southern brown bandicoots were also captured in Elliott traps in 2004 (0.29)