Strategic Red Fox control on bushfire affected public land in Victoria

Black Saturday Victoria 2009 – Natural values fire recovery program

Alan Robley, Graeme Newell, Matt White, Anna MacDonald, Stephen Sarre, Barbara Triggs, Janette Currie, Stephen Smith

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Department of Environment and Primary Industries
State Government Victoria

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Front cover photographs: Digital camera monitoring set-up (Jenny Nelson), Red Fox (Alan Robley), Smoky Mouse (Peter Menkhorst).

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Acknowledgements

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In 2013, the former Department of Sustainability and Environment (DSE) and Department of Primary Industries (DPI) became the Department of Environment and Primary Industries (DEPI). To avoid confusion, this report retains the names of the former departments where it refers to arrangements at the time the project was conducted.

Summary

This project aimed to protect and assist recovery of native fauna by reducing the impact of introduced Red Foxes in fire-affected areas following the 2009 Black Saturday bushfires.

A new evidence-based method for identifying strategic areas for post bushfire, fox control was developed based on the use of Species Distribution Models and the program Zonation. This process identified the eastern section of the Kilmore East–Murrindindi Fire Complex as the prime location for Red Fox control and associated monitoring and evaluation.

Fox control was implemented at four fire areas – Beechworth-Library Road, Kilmore East-Murrindindi, Bunyip Ridge, East Tyers-Thomson – covering 295,985ha. Some 15,092 baits were deployed at 4,074 bait stations of which 3,094 were taken. Contractors, under supervision, undertook the work 19 months after the fire event.

DNA genotyping was unable to determine the effectiveness of the eight-week fox control program due to the low sample size (n=55). The overall camera capture rate for Red Foxes increased from 2.2 during the pre-control survey to 8.6 in the post-control survey. The reasons for this are not completely apparent, however, juvenile animals were observed only during the post-control survey, suggesting that young dispersing animals may have been exploring the habitat during this phase.

The most common fox prey item was mammalian, comprising Brushtail Possum (*Trichosurus* sp.42%) most likely *T. cunninghami*, followed by Swamp Wallaby (*Wallabia bicolor*; 14%) and European Rabbit (*Oryctolagus cuniculus*; 11%). Birds, insects and plants were also consumed.

The proportional composition of dietary items may not be an indicator of the impact Red Foxes are having on native species. Species that were rare in Red Fox scats were Feathertail Glider (*Acrobates pygmaeus*), Sugar Glider (*Petaurus breviceps*), Greater Glider (*Petauroides volans*), Common Ringtail Possum (*Pseudocheirus peregrinus*) and Eastern Pygmy-possum (*Cercartetus nanus*; near threatened). Post-fire predation in fire impacted habitats may have an important role in the resilience of ecosystems subjected to fire.

The occurrence and distribution of native species provided baseline data for species considered at risk from Red Fox predation in the fire-affected areas. We recorded 36 camera detections of 12 species across four fire severity categories. In proportion to the camera trap nights in each burn category the majority of captures were within the Severe Scorch category (15.6). In the 100% Burnt and Light Scorch category camera capture rates were 8.3 and 8.1 respectively and in the Moderate Scorch category they were 5.2 per 100 camera nights. Only *Antechinus spp.* and Swamp Wallaby were recorded in the 100% Burnt areas and House Mouse (*Mus musculus*) was only detected in the Light Scorch areas.

The most commonly captured species on cameras were Swamp Wallaby and Mountain Brushtail Possum. Wallabies were most often captured by cameras in both the Burnt and Severe Scorch categories as were *Antechinus* spp. (both 4.2 and 3.1 captures/100 camera trap nights), while Mountain Brushtail Possum were most often captured in both the Severe Scorch and Light Scorch areas equally (2.1 and 2.2 respectively). Bush Rats (*Rattus fuscipes*) were captured twice as often in Severe Scorch areas (2.1) in relation to the other categories. The threatened Smoky Mouse (*Pseudomys fumeus*) was recorded from only one site, and this was in a Severe Scorch area.

Occupancy estimates were determined for seven species detected by cameras, with the exception of Echidnas (*Tachyglossus aculeatus*) for which there were too few encounters. There was a significant positive effect of Red Fox control on Superb Lyrebirds (*Menura novaehollandiae*), and a significantly

negative effect on small mammals. There was a substantial, but not statistically significant, decrease in Feral Cats (*Felis catus*) post-control.

The ability of the monitoring program to provide robust evidence of a native species' response to post-fire Red Fox control was constrained by the reporting timeframe and time-since-fire. The success of the long-term monitoring program will be determined by the availability of resources and the ability to obtain additional monitoring from other sources, such as postgraduate studies at universities. The monitoring program will provide valuable information on the presence and distribution of a range of native species, and this information enhances our understanding of the statewide distribution of these species.

Preparedness recommendations

This project has contributed to the knowledge and processes that underpin an enhanced response to future fire events.

Strategic planning could be enhanced by developing the data sets and information tools necessary to prepare for future emergency events in which predation may be a significant risk. Forward preparation of mapped locations for priority control of pest animals, with or without a major disturbance, would benefit rapid response to emergencies. It would also enable priority areas for predator control to be targeted prior to the potential negative effects of fire.

Pre fire data on predators and prey populations, and a capacity to rapidly acquire data on predator and prey populations immediately following fire would be beneficial, including the option of using trained dogs for scat collection.

As predation is likely to have its most significant effect immediately following a fire event, early access to funding, even in relatively small amounts, would enhance the capacity for rapid response and more effective outcomes.

Preparation of standard monitoring and recording systems (e.g. for bait take data) and tools, such as smartphone applications, would ensure appropriate and comparative data was being recorded across a wide range of users involved in implementation of predator control programs.

Project recommendations

The following recommendations are made to guide future projects:

Planning – Issues associated with such factors as inclement weather, difficult terrain, poor access and track conditions, fuel reduction burns, animal behaviour etc. need to be factored in when planning future fox control programs. Flexibility should be built into the program to cater for these variables.

Document preparation and timing – In planning future programs, required approvals and documentation (such as the PV/DSE Application to Control Pest Animals documents) should be obtained well beforehand to avoid delaying commencement of a program.

Risk Identification and Management – Due to the remote and rough nature of the program area, contractor and supervisor safety needed careful consideration. Potential risks can be mitigated through the use of well maintained vehicles equipped with UHF and trunk radios, high gain mobile phone antennas, recovery equipment, first aid, personal locator beacons, personal protective equipment, etcetera and by way of communication protocols such as checking in and out of areas by text message and leaving daily route/location details with relevant supervisors and at work centres. These equipment and procedural requirements should be incorporated into job safety documents.

Communications – As Shire mailout lists will not reach all properties, future projects should anticipate the need for additional, hand-delivered, landowner notifications. Additional signage and media would be useful to alert the public to the program and its value. Increased interaction and engagement with user groups and the community prior to a baiting run to ascertain their recreational habits and possibly modify the baiting areas would be beneficial.

Use of bait station cameras – More extensive use of remote cameras at selected bait stations would provide more comprehensive monitoring data, particularly where there is a risk of off-target bait take to identify species potentially affected.

Ongoing fox control – A fox baiting program should be undertaken over an adequate length of time to maximise effectiveness and efficiency of the program. The timeframe could be based on the degree of redevelopment of habitat, which may take 3–5 years depending on vegetation type and site variables.

Suppression of the Red Fox population – Bait take data should be analysed for each round of baiting. Mitchell and Balogh (2009) describe methods for converting bait take data into an index of abundance using frequency/density transformation.

Digital cameras (maximum two per km^2 set for a minimum of 21 days using a predator lure) can also be used to assess trends in occupancy. This approach could also be used to assess trends in occupancy rates of Feral Cat. It would not be appropriate to use digital cameras for assessing changes in native species at the same sites as for introduced predators, as this combination would require luring introduced predators and native species to the same site.

Monitoring changes in predator diet – Continued annual assessment of the proportional composition of Red Fox diet would provide information on the spatial and temporal change in distribution of a range of native species that were not detected by camera survey. Scat collection should occur at the same time and place as in this study.

Monitoring changes in native species – Further interrogation of the model output to identify those species that comprised the overall biodiversity benefit described in the model. This information could be used to better target monitoring methods to those species.

Site occupancy may change over years as populations change. When sites are surveyed between these periods of change, over a number of years, the approach described here can be combined with a robust mark–recapture approach (Pollock *et al.* 1990). Sampling, using digital cameras, should be repeated at the same site each year and continued for several years. The change in occupancy rates over years could then be modelled as a function of site colonisation and extinction rates, analogous with birth and death rates in an open-population mark-recapture study, and explanatory variables such has fire history, presence of predators, and changes in vegetation structure can be incorporated into the analysis.

While the monitoring and evaluation of selected indicator species has been designed using the best available data, it is strongly recommended that in future, after the first year, the data collected is used to reassess the sampling design and, if necessary, amend the monitoring program.

1 Introduction

1.1 The Black Saturday bushfires

The Black Saturday bushfires that ignited in Victoria on 7 February 2009 consisted of 14 major fires that burnt 430,000 hectares (Figure 1). Of the area burnt, 69% or 284,510 hectares, is public land of which 25% contains high biodiversity values protected in conservation reserves (DSE 2010).

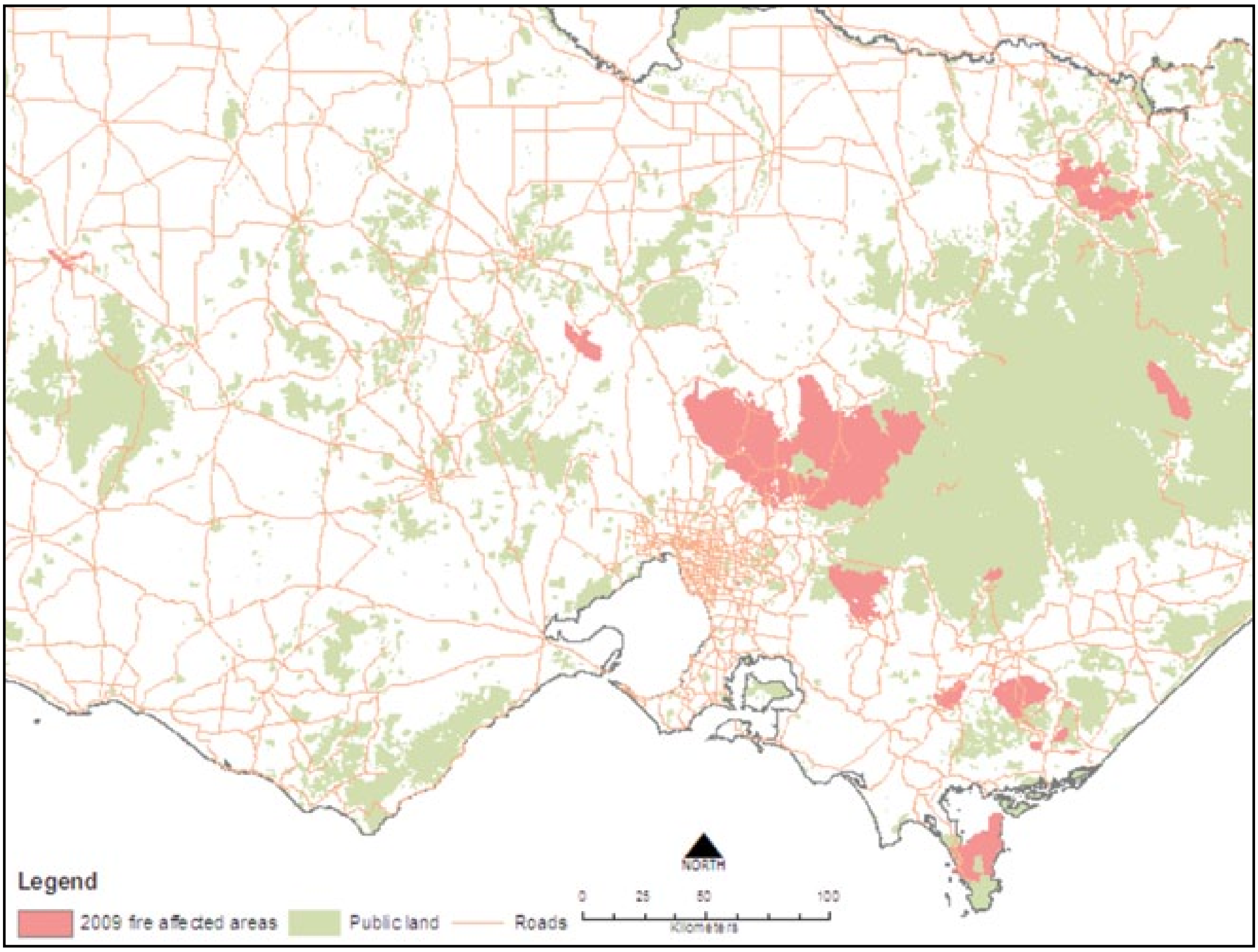
Shortly after the fires, the Department of Sustainability and Environment (DSE) and Parks Victoria (PV) reviewed existing data to determine what natural assets and populations of fauna and flora were at risk. This task identified that within the area burnt there are 27 *Environment Protection and Biodiversity Conservation Act 1999* listed (nationally significant) species, and 19 *Flora and Fauna Guarantee Act 1988* listed species potentially affected by the fires, along with numerous threatened ecological communities (e.g. Cool Temperate Rainforests) and other ecological communities of concern (e.g. ash eucalypt forests and sub alpine bog communities). Immediate threats and required actions to address those threats to these species and ecological communities were identified by fire area.

1.2 Predator issues following bushfires

The scale and intensity of the Black Saturday bushfires significantly and directly impacted on populations of fauna species. Ground dwelling and small arboreal mammals rely on the under and mid-storey vegetation for shelter and food. The intensity of the Black Saturday fires removed the under- and mid-storey layers over large areas of parks and forest. Consequently, any remaining fauna are forced to cover greater distances over open ground to find adequate food and/or shelter, which leaves them vulnerable to predation by predators such as the introduced Red Fox *Vulpes vulpes*. For species already under threat for a variety of reasons before this fire event, the risk of predation might mean that local populations of native fauna will not recover.

Immediately following the fires, as soon as human safety in the fire area could be assured, urgent, small-scale, targeted predator control was undertaken at several locations — Kinglake National Park (to protect Brush-tailed Phascogale *Phascogale tapoatafa*), Wilsons Promontory (New Holland Mouse *Pseudomys novaehollandiae*), Bunyip State Park (Southern Brown Bandicoot *Isoodon obesulus*, Swamp

Figure 1. The 2009 fire-affected areas considered for Red Fox control.



Antechinus *Antechinus minimus*) — to protect threatened species at risk from foxes and cats.

Following the establishment of the recovery program, and after reviewing previous post-fire predator control methods, DSE and PV decided to take a strategic approach to fox control by targeting effort (time, money and other resources) at locations and species that would yield the greatest benefit. Priority locations were selected from a spatial analysis of the distribution of ranked rare or threatened species and other species considered as being at risk from fox predation within or adjoining bushfire-affected public land. This identified and prioritised areas for targeted control works. This new approach, documented in this report, is intended to assist future recovery programs.

1.3 The project

The Project, initiated in 2010, was developed within the program 'Rebuilding Together' funded by the Victorian and Commonwealth governments' Statewide Bushfire Recovery Plan, launched October 2009. In line with previous practices, public land management agencies submitted post 2009 fire project proposals which included multiple bids related to predator control programs across bushfire-affected areas in eastern Victoria. Some proposals included larger aggregated areas across public land tenures while others were for smaller areas managed by a single land manager. Instead of distributing funds based on individual project proposals, the Statewide Natural Values Fire Recovery Implementation Team (NVIT) worked with proponents of Red Fox control to develop a single, cross-tenure project with strategic components (i.e. this project). A separate project to assess a bait for Feral Cat *Felis catus* management was also funded (Johnston 2012).

The NVIT oversaw all natural recovery projects and regular progress reporting to the Victorian Bushfire Reconstruction and Recovery Authority (VBRRA). The NVIT appointed a multi-agency Predator Project Control Board (PPCB) to provide governance and technical advice and direction for this project.

The project was led by Parks Victoria but delivered tenure blind within bushfire-affected public land managed by the DSE, PV and Melbourne Water (MW). Project delivery involved an intensive 1080 fox baiting program, coordinated across targeted areas. The aim was to reduce predator populations to a level that enables prey species to increase their populations and/or distribution back into recovering, fire-affected habitats. Red Fox control using baiting, was implemented between early 2010 and December 2011.

The Arthur Rylah Institute for Environmental Research (ARI) was commissioned to develop an approach for identifying and selecting sites where investment in post-fire predator control was most likely to provide the maximum benefits for biodiversity protection, and to implement a monitoring program that a) assessed the short term response of native species to post-fire Red Fox control and b) laid the foundation for a longer term monitoring program should further funding become available. Time constraints and available resources meant that no control sites, where no fire and/or no Red Fox control were imposed, could be included for comparison. This limitation, and the time between the fire event and the commencement of monitoring (19–20 months post-fire), restricted the investigation into the impacts of post-fire predation and the response of native species to Red Fox control.

Following the period of assisted recovery by this project, and the return of vegetation cover, it is anticipated that predator control will be delivered through agencies' ongoing programs. An example of this is presented in Section 4.

1.3.1 Project objectives

The outcomes sought from the project were:

- A priority ranking of each species at risk based on their susceptibility to predation by foxes
- The occurrence and modelled spatial distribution of those species across bushfire-affected public land.
- The development of prioritised target areas for predator control treatment based upon species threat assessment, fire intensity and severity and regional delivery capacities.
- A reduction in predation pressure on species at risk from predation and including mammal, bird, reptile and amphibian species in the fire-affected areas, allowing for the recovery of these pre-fire occurring species.
- The development of appropriate and consistently implemented standards relating to pest predator control monitoring protocols and reporting procedures.
- An improved understanding of the effectiveness of post-fire pest animal control on predator populations.
- An improved understanding of the post-fire recovery of threatened mammal populations.
- The identification of links and the development of management delivery efficiencies with the Fire Recovery Pest Plant Control Project and researchers on other pest animal programs such as the Southern Ark, Glenelg Ark and Otway's pest animal research program.
- The provision of accurate data and mapping information with an integrated mapping and data capture system to ensure accuracy, consistency and portability between agencies for all spatial information.
- To contribute to community recovery through employment opportunities and increased community engagement in, and understanding of, pest animal and threatened species control and monitoring programs.

1.3.2 Project components

The project consisted of three key components:

- Development of a new method for identifying strategic areas for fox control
- Field implementation of Red Fox control
- Monitoring of the effectiveness of the program.

1.3.3 Complementary projects and programs

In addition to this project, other predator control projects across bushfire-affected public land areas were being implemented. Where possible, projects were integrated, particularly when Red Fox was a priority for other projects. The Australian Government's Caring for our Country (CFoC) funded projects had some overlap but also involved wild dog control and control methods other than baiting. A Red Fox control project associated with environmental offsets for the Sugarloaf Pipeline in the Toolangi area was integrated into the field delivery of this project.

2 Identifying strategic areas for fox control

2.1 Introduction

The strategic planning component of this project aimed to develop an evidence-based, tenure-blind approach to identifying areas that should be targeted for predator control following bushfire. Effective fox control depends on large-scale, frequently-applied baiting, so the project sought to identify large areas where multiple assets could be protected. It also aimed to identify specific sites for monitoring and evaluation.

Strategic planning and monitoring components of the project were led by the Arthur Rylah Institute. The outcome was a series of mapped outputs that provide decision-support capabilities to targeted Red Fox control in fire-affected areas.

2.2 Strategic prioritisation method

Selecting Species Distribution Models

A series of systematic and statistically robust methods for producing and evaluating 'mapped' probabilistic Species Distribution Models (SDMs) for native fauna had previously been developed by the Spatial Ecology Group (G. Newell unpub. data) of the Arthur Rylah Institute. These SDMs were developed using location data from the Victorian Government's biodiversity databases.

From all known mammal, bird and reptile species that occur in Victoria, 126 species were selected for inclusion in the assessment of priority Red Fox control areas. Species that were omitted from the analysis were those for which reliable SDMs could not be produced for various reasons (e.g. data quality, water birds, species at the edge of their distributional ranges, migratory species with poorly defined habitats). A list of all species considered, along with their estimated risk of Red Fox predation as previously defined by Robley and Choquenot (2002), is provided in Appendix 1.

The SDMs in their native form are at a resolution of 25 m, but that was considered too fine a scale for this investigation. Consequently, all SDMs were resampled at 100 m resolution, with an extent covering the whole of Victoria.

Bushfire severity mapping

Following the 2009 bushfires, DSE developed a fire severity model from remotely sensed imagery, reflecting the degree of crown and understorey damage on an eight-point scale (Table 1). The modelled surface produced was used to differentially model the likely reduction in the probability of species distribution to the SDMs according to the weightings shown in Table 1. The degree of alteration applied to species distribution was set by consensus with the Predator Project Control Board and fauna experts from ARI.

Table 1. Degree of alteration applied to species distribution models in accordance with DSE's 2009 Fire Severity Class mapping.

Fire Severity Class	Description	Alteration level to SDMs (%)
1	Crown burn 70–100% crowns burnt in an intense overstorey burn with widespread crown removal and 100% understorey removed.	100
2	Crown scorch 60–100 % crowns scorched, some crowns are burnt an intense understorey fore with complete crown scorch of most tree and tall shrubs.	90
3	Moderate crown scorch 30–65% crowns scorched a variable intensity fire from warm ground burn with no crown scorch to an intense understorey fire with complete crown scorch of most tress and tall shrubs.	80
4/5a	Light or no crown scorch; understorey burnt 1–35% of crowns scorched, a light ground burn with patches of intense understorey fore, some crown scorch. May include areas of unburnt forest.	70
5b	No crown scorch; no understorey burnt <1% of crown scorched.	0
6	Burnt woodlands, unclassified.	80
7	Burnt grasslands.	80
8	Unburnt grasslands.	0

SDMs for the target species were assembled in two 'stacks' — one stack was the pre-fire or un-impacted state, and in the other stack each SDM model had the modelled damage applied.

Zonation software

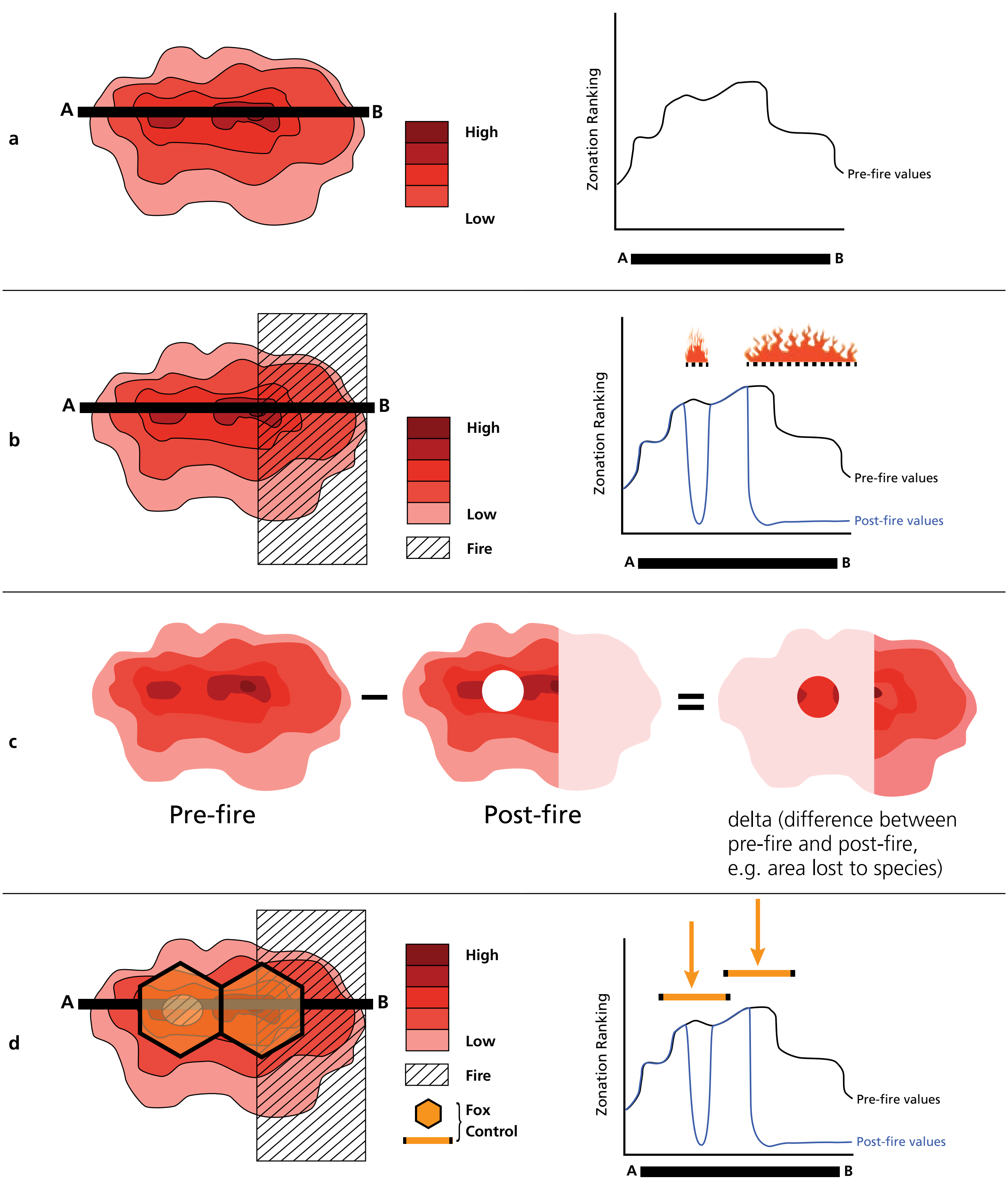
The 126 SDMs were integrated in a spatial optimisation using Zonation, a free software program for spatial conservation prioritisation (University of Helsinki 2010).

Zonation effectively addresses the problem of assessing 'maximum utility', taking into account distributions of biodiversity features, connectivity responses, priorities for features, and a variable emphasis on highest local quality. The main output of a Zonation analysis is a hierarchical ranking of priority for all cells in the landscape, which can be visualised as zoned maps.

The Zonation process determines the optimal sites for the conservation of the target species before the 2009 fires and compares this result with the areas impacted by the 2009 fires. The Zonation procedure sequentially and iteratively removes cells that are least important in the intersection of all of the spatial inputs in each analytical stack independently. All analyses used a 'warp factor' (the number of cells removed at each iteration) of 1000, so that a total area of 1,000 ha was removed across Victoria at each iteration. At this setting, each species model run took between 60 and 70 hours to complete. The size of the calculation involved (i.e. 126 species at 100 m resolution, with 8,136 columns × 5,771 rows = 4.7×10^7 cells per SDM) required a 64-bit beta version of the software that could run under Microsoft Windows 7. This version of the software was supplied directly by Dr Atte Moilanen (Academy Research Fellow, Vice-director of the Metapopulation Research Group, University of Helsinki).

The overall logic of the analytical approach in this study is shown in graphical form in Figure 2. For the pre-fire state, Zonation was used to produce a ranked surface of the biodiversity values across a landscape, which can be viewed as a 'map' and a cross-sectional 'profile' (Figure 2a). Similarly, a ranked surface can be developed using fire-impacted SDMs, and the difference between the pre-fire and post-fire ranked surfaces, can be calculated (Figures 2b and 2c). A further analysis that was developed during this study was to investigate the differences across the zones that were, and were not, directly impacted by the fires. Figure 2d represents baiting zones applied as a sampling approach across the landscape to calculate a Baiting Utility Index.

Figure 2. Analytical logic used in this investigation. (a) pre-fire ranked surface and profile of target fauna distribution, (b) difference calculated by comparing pre-fire and post-fire rank analyses, (c) scores differences shown in profile, (d) application of baiting efficiency units across both burnt and unburnt landscapes to calculate an index. High values represent higher species 'richness'.



2.3 Priority locations for Red Fox control and monitoring

The results of the Zonation analyses are shown in Figure 3a, which illustrates the statewide ranking of the 126 SDMs when all the species' distributions are weighted equally. This result can be compared with the same analysis when the ranking from Appendix 1 is applied (Figure 3b). There is little obvious difference when viewed using 10 value classes at the statewide scale, or at more localised scales such as that shown to the east of Melbourne, encompassing the Kilmore East–Murrindindi Fire Complex (Figure 4). For consistency, all subsequent comparisons between model outputs are shown using the ranked species approach.

Figure 5 compares Zonation outputs for pre-fire and post-fire analyses. This comparison highlights that, while significant areas of high value locations for the suite of species considered in this study were impacted by fire, there are also many highly ranked locations immediately outside the fire-affected areas. This suggests that the interface between these areas may warrant a high priority for predator control efforts. Although Figure 8 only shows the area around the Murrindindi–Kilmore fire area, the analyses were conducted on a statewide basis to enable comparisons systematically between each of the fire areas as well as within individual fire zones. The full comparison is omitted here for the sake of brevity.

Figure 6 shows the difference between pre and post-fire models using the same analytical approach (i.e. weighted SDMs impacted by fire, or not).

Figure 3a. Outputs of Zonation analysis: rank of all 126 species prior to being altered by the 2009 fires. All SDMs are weighted equally, and data are grouped into 10 classes.

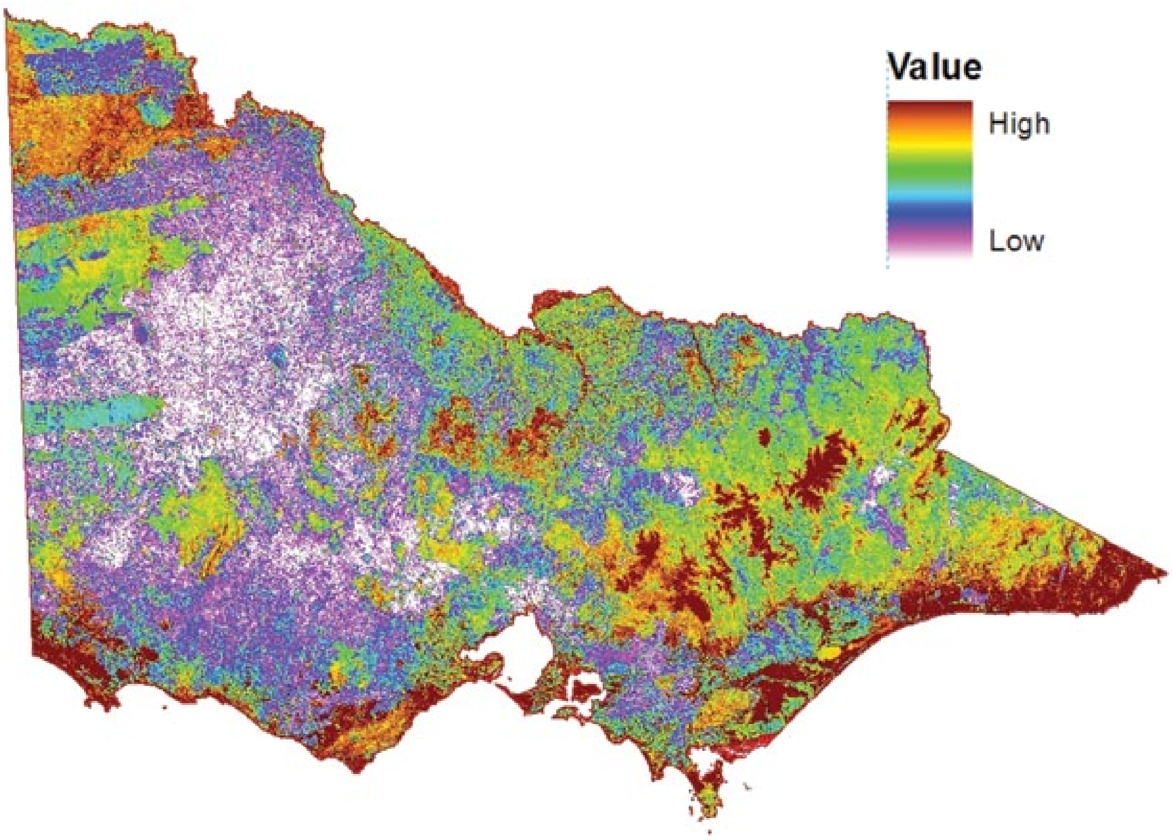


Figure 3b. Outputs of Zonation analysis: rank of all 126 species not impacted by fire. SDMs are weighted according to the schedule in Appendix 1.

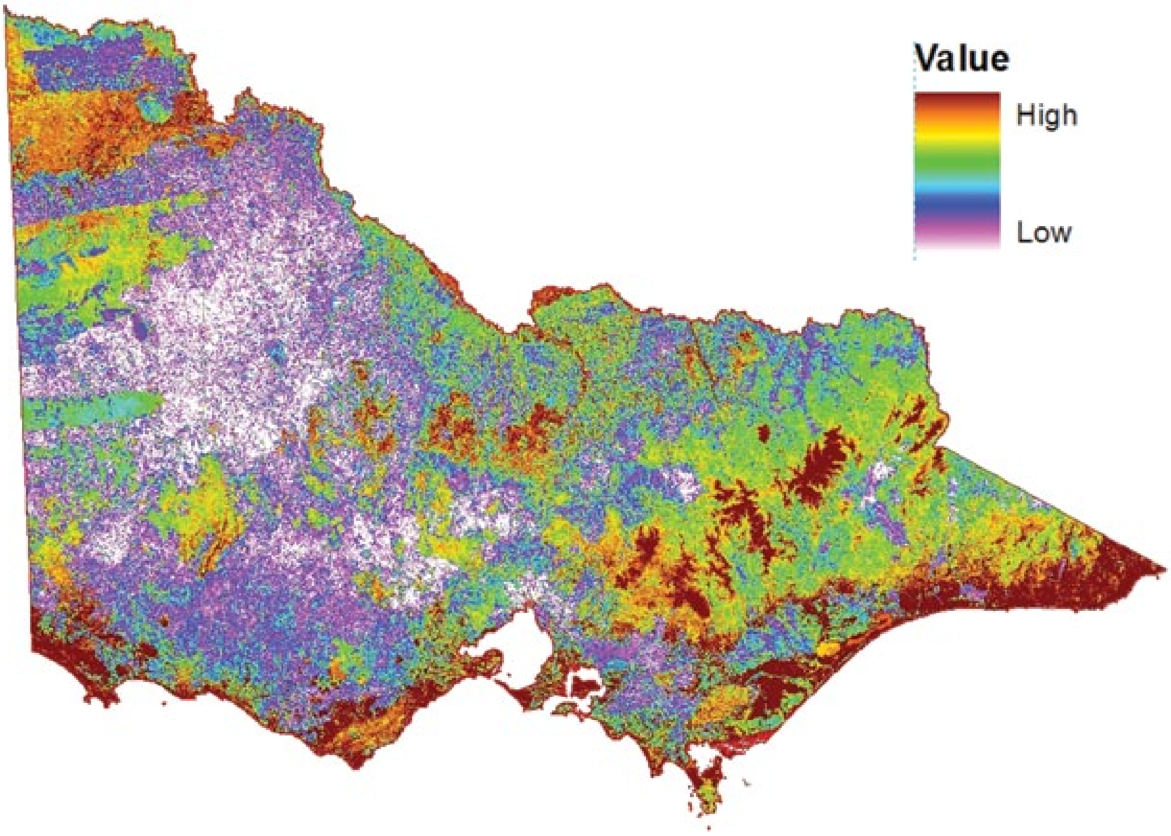
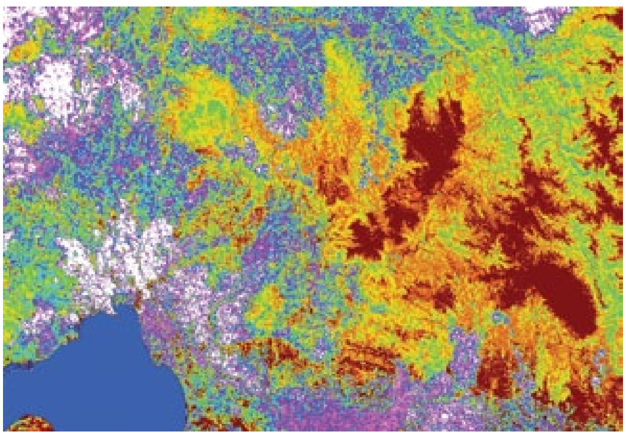
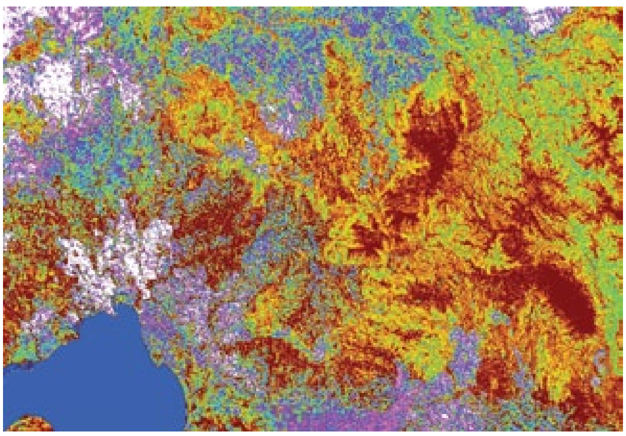


Figure 4. Comparison of Zonation analysis using ranked and equal rank approaches.



Weighted Equally



Weighted according to Appendix 1

Figure 5. Kilmore East-Murrindindi Fire Complex comparisons of pre-fire and post-fire ranked surfaces.

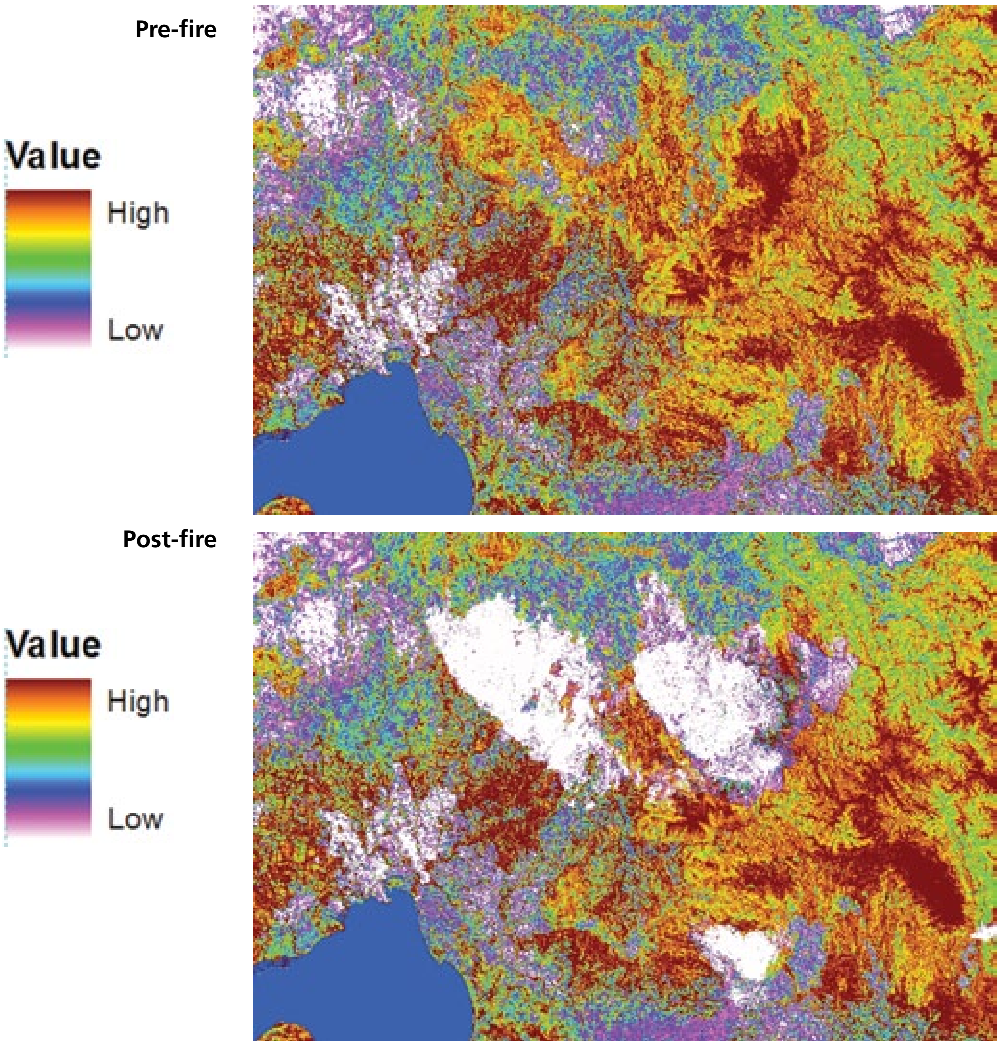
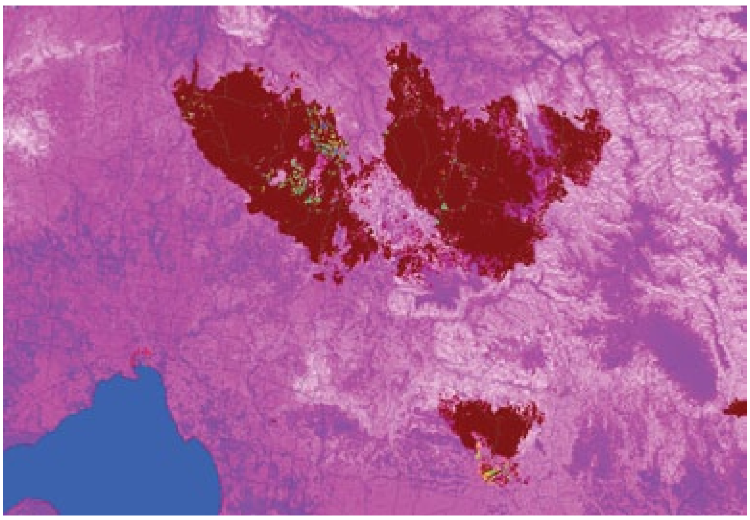


Figure 6. Difference between pre-fire and post-fire models shown in Figure 5. Darker areas highlight areas of greatest impact.

Difference in fire impact on fauna distributions.



The next part of the analysis considered not only how the SDMs within the fire area were directly impacted, but also considered that these areas were likely to be recolonised from adjacent unburnt areas. It was recognised that although Red Fox control is focused on areas that are directly impacted by the fires, it is also important to provide support, in terms of Red Fox control, to adjacent extant populations. In this case we were interested in analysing priorities not just within the fire area (i.e. the difference between pre-fire and post-fire analyses) but also across the fire boundary, to include areas that had been impacted by fire and areas that would revegetate over a period of time, and the adjacent localities that are the most likely sources of recolonisation.

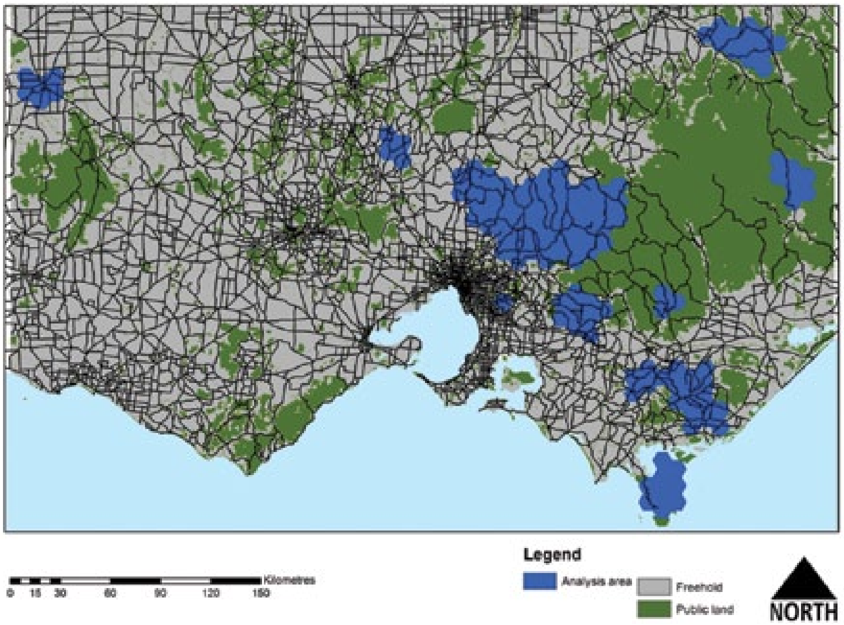
Investigating the ranked priority across the fire boundary required an estimate of the Red Fox control baiting area. For this study we estimated the area of influence of an individual Red Fox control zone to be 10 km^2. This is shown diagrammatically in Figure 2d, where a sampling unit is placed across the landscape. Hexagonal areas rather than circular were used to maximise packing efficiency and spatial geo-processing analyses. These sampling units were used to cover all areas impacted by the 2009 fires and buffered by 10 km (Figure 7) to calculate a baiting utility index.

The Baiting Utility Index was calculated for each hexagonal 10 km^2 window using the formula:

Baiting Utility Index = maximum range of difference between pre-fire and post-fire analyses × mean pre-fire weighting.

The output from this calculation is shown in Figure 8 for all tenures and in Figure 9 where areas that are predominantly private estate are removed from further consideration. The outputs shown in Figure 8 were then available for a subsequent investigation of how these priority areas that have been identified (1) align with the location of previously used bait stations, and (2) access and practicality issues such as the location of roads and access tracks.

Figure 7. Baiting utility study area across fire-affected areas and the hexagon sampling units (10 km^2) aligned with the fire-affected area in the Kilmore East–Murrindindi Fire Complex.



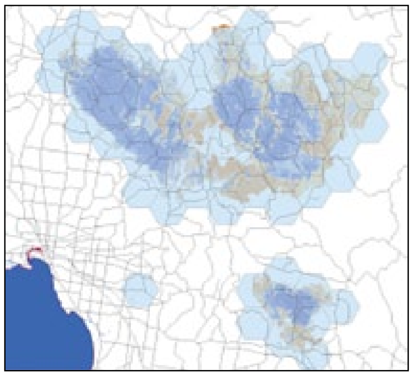


Figure 8. Baiting Utility Index displayed across all land tenures.

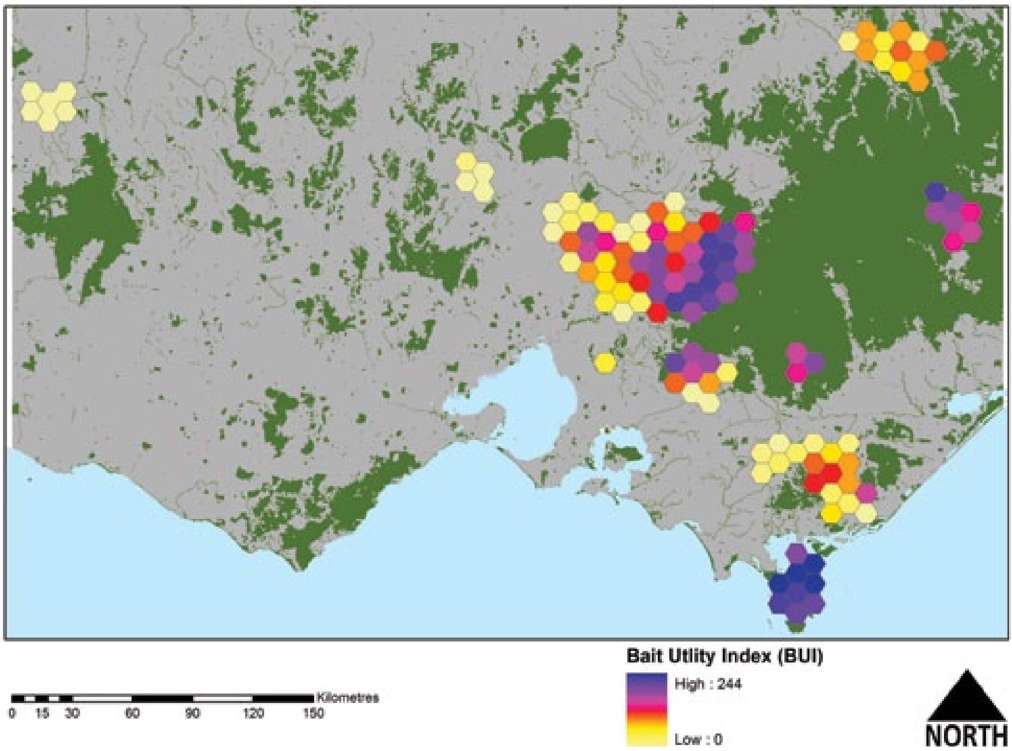


Figure 9. Baiting Utility Index confined to public land. Areas on private land or where 10km^2 hexagon falls mainly on private land is shaded black.

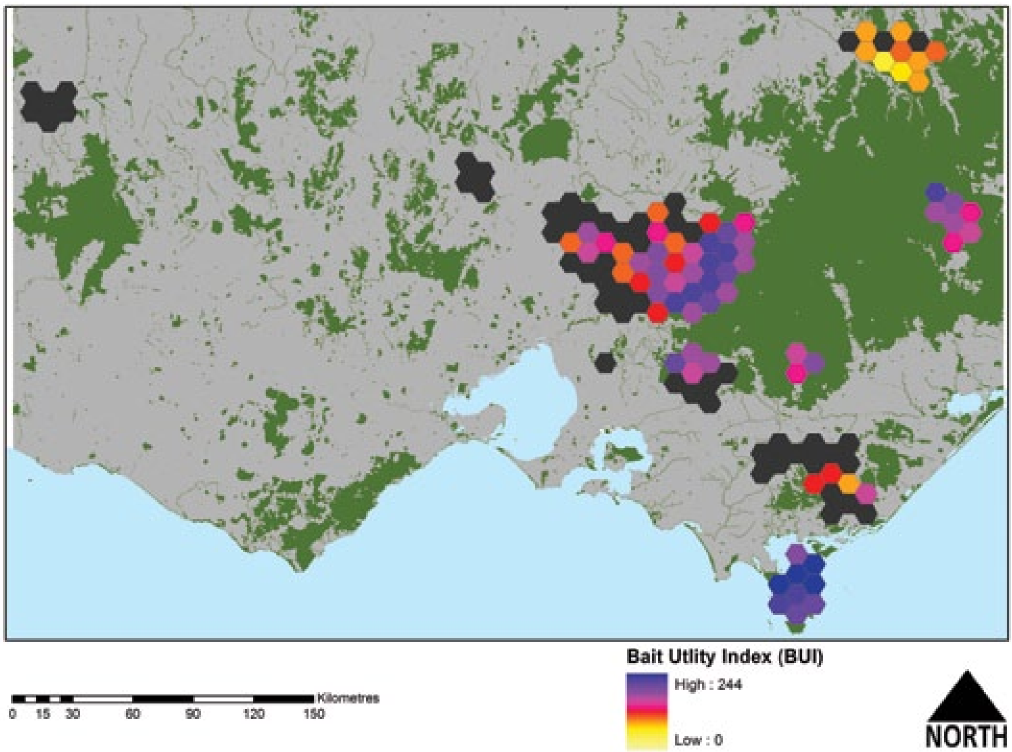
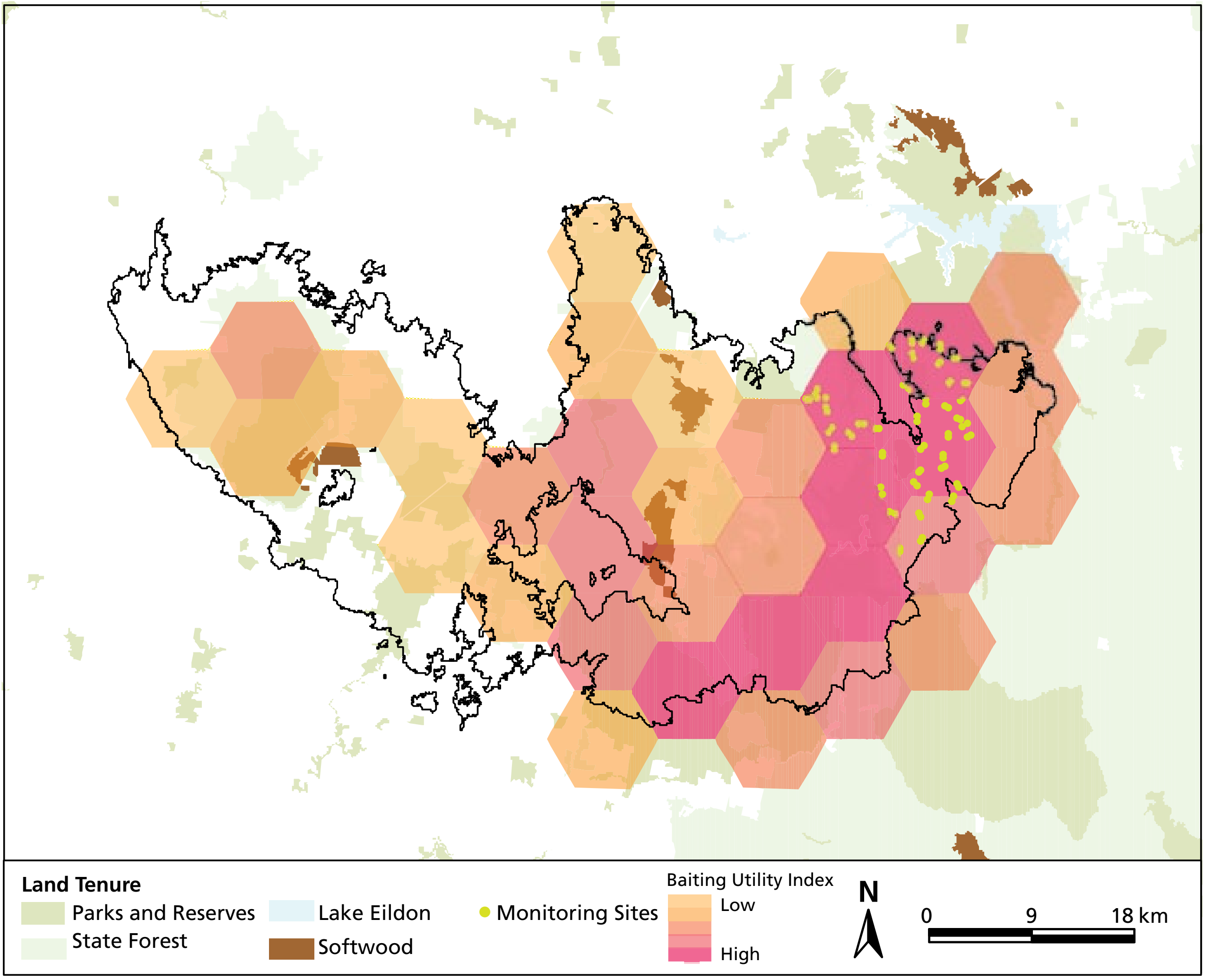


Figure 10. Priority areas for monitoring and evaluating Red Fox control in the Kilmore East-Murrindindi Fire Complex. Yellow dots represent individual monitoring sites.



Areas where Red Fox control and monitoring would be implemented within the zoned map were then defined by the Predator Project Control Board and regional land management staff. The process of site selection considered practical issues of access, resource capacity and the spatial scale at which Red Fox control could be implemented effectively. Large-scale, frequently-repeated baiting programs are needed to effectively reduce fox numbers. Other Red Fox control activities, funded under the Caring for Our Country Bushfire Recovery program and regional DSE, Parks Victoria and Melbourne Water initiatives, were also considered when selecting the monitoring and evaluation sites. This process identified the eastern section of the Kilmore East–Murrindindi Fire Complex as the prime location for Red Fox control and monitoring.

High value BUI hexagons along with the following criteria were used to determine treatment extent within the selected prioritised areas.

- **The size of the modelled target area** – The minimum target area chosen for effective treatment was 10,000 hectares. Potential fox control areas less than 10,000 hectares or geographically isolated areas, or areas with delivery issues associated with access, topography or other difficulties, were excluded from treatment.
- **Capacity to deliver** – Public land management agencies had varying capacity to deliver in different circumstances or to deliver particular project components.
- **Access** – Seasonal restrictions applied to some areas as a result of seasonal road closures. In some areas road coverage and road conditions were considered.

- **High visitation or recreational activity nodes, townships or housing –** Baiting was generally excluded from these areas and buffers applied.
- **Pre-existing and alternative funding arrangements for predator control project delivery.**

As a result of these analyses and practical considerations, Red Fox control was implemented at four fire areas – Beechworth, Kilmore East-Murrindindi, Bunyip Ridge and East Tyers-Thomson – covering 295,985 ha.

The individual monitoring sites within the selected area for monitoring and evaluation are indicated by yellow dots in Figure 10. At each of the 40 monitoring locations, a fire severity score was recorded (Table 5, p24).

2.4 Strategic planning discussion

The process applied here – using spatially ranked aggregations of SDMs to inform management – is one that has only been used sparingly in the past. This is primarily due to a limited number or lack of useful SDMs and a lack of appropriate software to handle the complexities of spatial optimisation of such data. To our knowledge, this is the first time that such an approach has been applied to prioritising predator control actions after bushfire, and certainly in an exercise that has been undertaken systematically at a state-wide scale and for a large number of susceptible species.

An approach that is transparent and allowed managers to make decisions on where to allocate limited resources and focus monitoring and evaluation activities was developed and implemented.

While this approach is unique in its scale, breadth and systematic approach, it does involve the following assumptions, limitations and caveats:

- The primary contrast being made is between a pre-fire and post-fire stack of 126 SDMs. This ignores any earlier fire history and includes species that do not occur in the bushfire-affected areas.
- The native species monitoring was focused on mammal species, while the complete stack of 126 species in the SDMs included birds, reptiles and amphibians at risk from fox predation. Thus, site selection for fox control may have been driven by the presence of other vulnerable species rather than mammals.
- Although the SDMs have been developed using a systematic approach, they all use a generic set of predictor variables and are therefore not finely tuned for each species. SDMs that include refinements may have advantages in future studies.
- The assumption is that in the Severe Scorch category, which represents 70–100% of crowns burnt in an intense overstorey burn, with widespread crown removal and 100% understorey removed, and that all individuals of all species are killed, may not be true in all cases. This represents a conservative approach to altering the species distribution after a fire event.
- The assumption of a 10 km^2 area as an effective Red Fox control zone may or may not be appropriate (i.e. it was an arbitrary decision made in the absence of data), and future research may refine the control area.
- In the absence of a well-resolved Red Fox SDM to represent a constraint surface, an even level of impact of Red Foxes across all of the Victorian landscape was assumed. However, this is almost certainly untrue. Future improvements in a Red Fox SDM could greatly improve analyses such as this.

Outputs from the Zonation analyses are focused on species' complementarity (i.e. combinations of species in space), and not necessarily species' richness at any location. Although analyses using the same 126 SDMs with a goal of maximum species' richness would probably provide a slightly different series of outputs, we believe the rank surface output would be quite similar to that developed here.

Furthermore, although Zonation analysis has involved a systematic approach to defining localities for optimum predator control efforts, the final part of the analysis that would consider the optimal positioning of individual bait stations has not been described here. Field site selection should consider access via roads and tracks, distance from these access routes from which bait stations could be placed, local tenure issues (i.e. zonation analysis does not consider different categories and land management activities by different government agencies), efficacy of baiting techniques in different habitats, etc.

The analysis undertaken in this project constitutes a systematic assessment of the likely benefits of predator control at any particular location within the general areas impacted by the 2009 fires. The systematic process that has been developed and applied here may be useful in addressing similar questions and needs in the future.

3 Field implementation of Red Fox control

3.1 Introduction

Following the development of the spatial analysis for predator control prioritisation using the Species Distribution Models (SDM), as outlined in section 2.2, the Predator Project Control Board selected bushfire-affected areas for fox control based on an Index of values and risk (see section 2.3), practicality and relationship to other fox control activities.

Parks Victoria led on ground project implementation in all areas except Beechworth-Library Road, which was led by DSE. Intensive 1080 fox baiting was used across targeted areas within bushfire-affected public land managed by the Department of Sustainability and Environment (DSE), Parks Victoria (PV) and Melbourne Water (MW). Areas selected for control are listed in Table 2. Baiting occurred on burnt as well as adjacent unburnt land.

The on-ground delivery (baiting) for this project occurred between October 2010 and December 2011. In the Kilmore East-Murrindindi Complex, this project worked in conjunction with a Caring for Our Country (CfoC) predator control project which commenced post-fire in 2009–10. Integrating the two programs resulted in baiting over a longer time period and enabled protection over a larger treatment area.

3.2 Field implementation methods

Pre-prepared baits ('Fox off' or 'De-Fox') containing 3 mg of Sodium Monofluoroacetate (1080) were buried to a minimum depth of 100 mm within sand pads, to reduce the likelihood of non target bait takes and to facilitate monitoring. These pads were established at intervals of approximately one kilometre.

Program managers complied with the legislative requirements for 1080 baiting specified in the DPI Standard Operating Procedures & Directions for Use document (DPI 2010). This specifies requirements for bait supply, handling, record keeping, neighbour notifications, signage (Figure 15), bait placement and replacement (Figure 16), risk assessment, disposal and incident response. In addition, PV and DSE completed and had approved 'Application to Control Pest Animals' documents.

Due to the often remote and rough terrain, careful planning for risk management and occupational health and safety needs for area staff and contractors was undertaken.

Local contractors were engaged to undertake the baiting programs in each fire area. All contractors were required to operate in accordance with the *Agricultural and Veterinary Chemical (Control of Use) Act 1992* and hold a Commercial Operators Licence with a vermin endorsement or a Licence to use Pesticides.

Guidelines to establish bait stations (see Appendix 3), were followed by contractors while undertaking the project.

The areas baited within and adjacent to fire areas are shown in Figures 11–14. Table 3 summarises the baiting program within each fire area.

Table 2. Description of target areas selected for post-fire Red Fox predator control. SF = State Forest, NP = National Park, SP = State Park, RP = Regional Park.

Bushfire-affected Areas targeted for Red Fox control	On ground delivery lead agency	PV Land units treated	DSE land units treated	Area burnt Total (ha)	Area public land (ha)
Beechworth-Library Rd	DSE	Mt. Stanley Scenic Reserve	Stanley SF Wooragee SF	33,830	21,400
Kilmore East-Murrindindi Complex	PV	Lake Eildon NP, Cathedral Range SP, Yarra Ranges NP	Big River SF, Rubicon SF, Marysville SF, Toolangi SF, Upper Yarra SF, Pauls Range SF.	293,925	193,470
Bunyip Ridge	PV	Bunyip SP, Kurth Kiln RP.	Yarra SF, Tarrango SF	26,440	18,900
East Tyers-Thomson	PV	Baw Baw NP, Moondarra SP.	Tanjil SF, Thomson SF.	1,780	1,780

Table 3. Strategic Red Fox predator control program, summary of operational statistics for areas treated.

Operational statistics summary - October 2011– Dec 2012					
Bushfire-affected Area	**Total Area treated (hectares)**	**No. bait runs/ management zones**	**Area of bait runs (range)**	**No. of pulse treatments delivered**	**Pulse duration**
Beechworth-Library Road	4200	2	1,400–2,200ha	1	36 weeks
Kilmore East-Murrindindi Complex	153,000	6	15,000–30,000ha	4	7–8weeks
Bunyip Ridge	40,985	3	11,000–16,500ha	3	5 weeks
East Tyers-Thomson	30,000	2	15,000ha	3	6 weeks
TOTAL	228,185ha	12	1400–30000ha		av. 6weeks

Figure 11. Area of public land in which Red Fox baits were laid in the Beechworth-Library Road fire area.

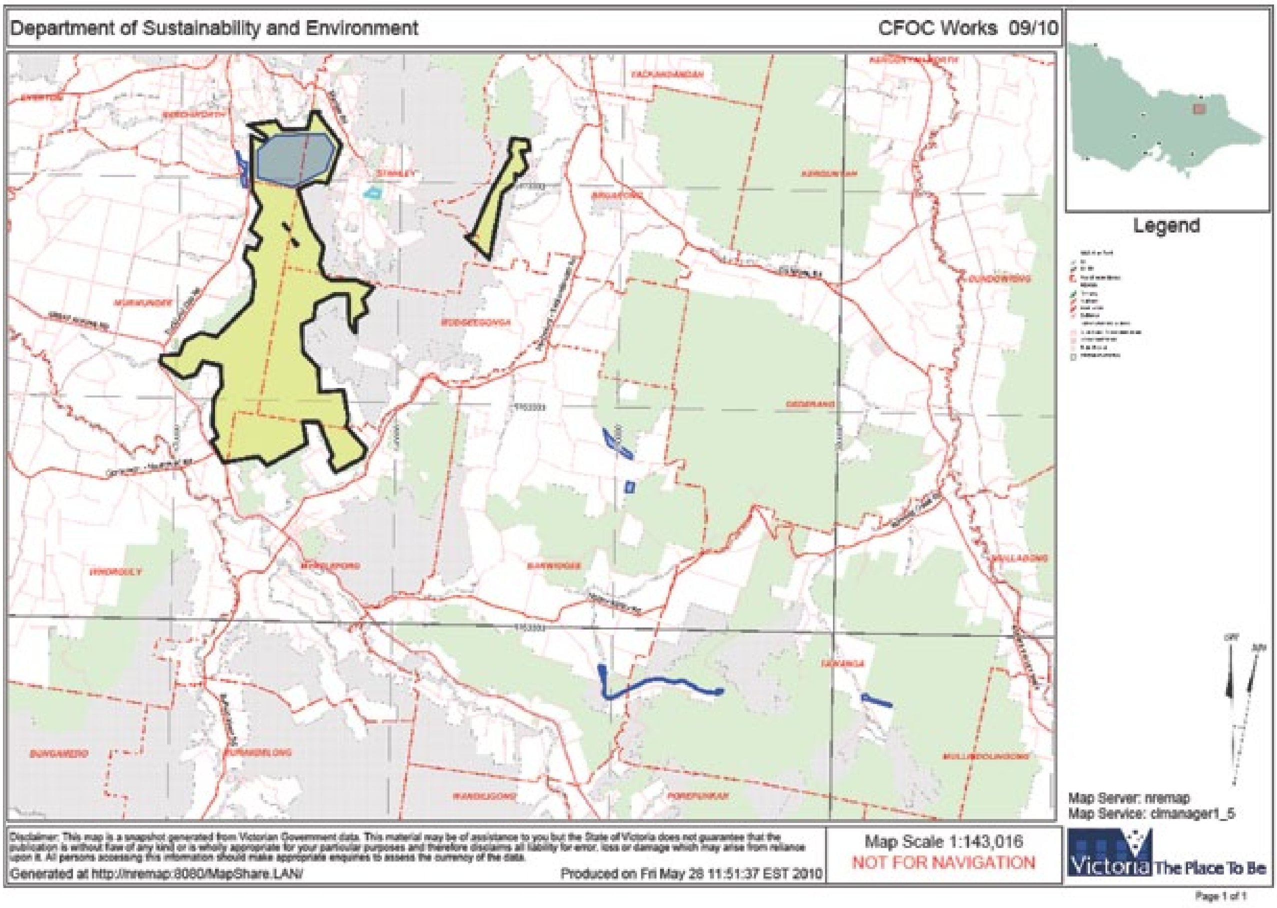


Figure 12. Area of public land in which Red Fox baits were laid in the East Tyers-Thomson fire area.

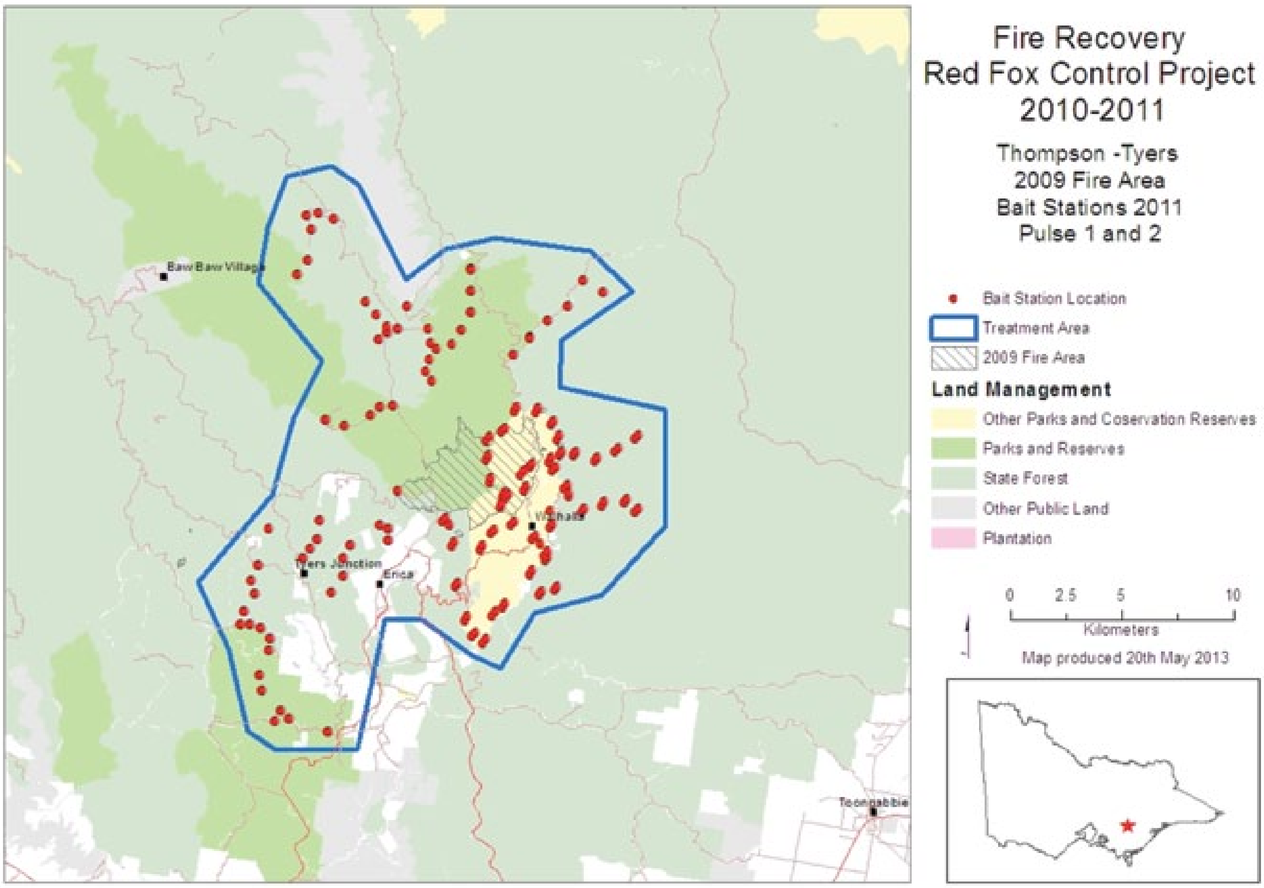


Figure 13. Area of public land in which Red Fox baits were laid in the Kilmore East –Murrindindi Complex fire area.

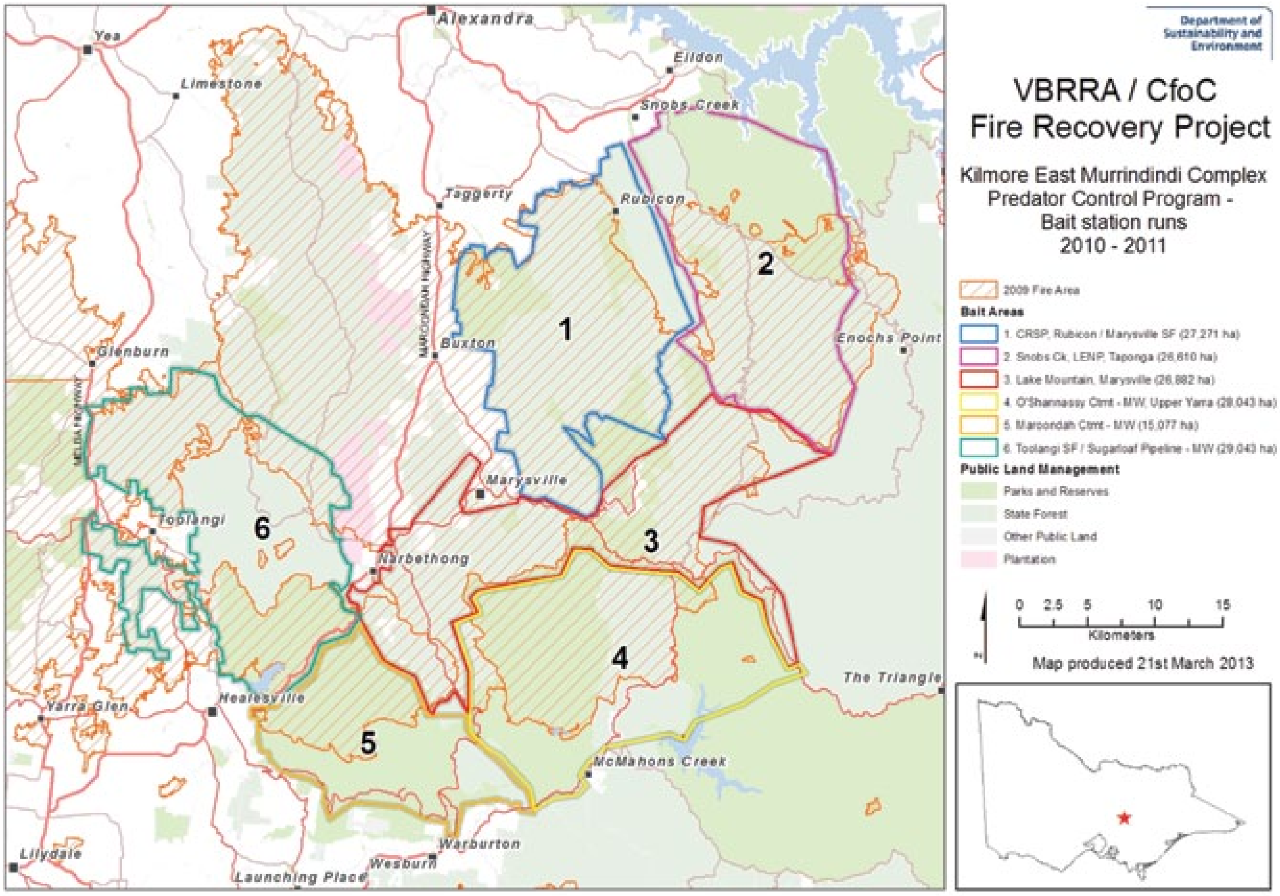


Figure 14. Area of public land in which Red Fox baits were laid in the Bunyip Ridge Fire area.

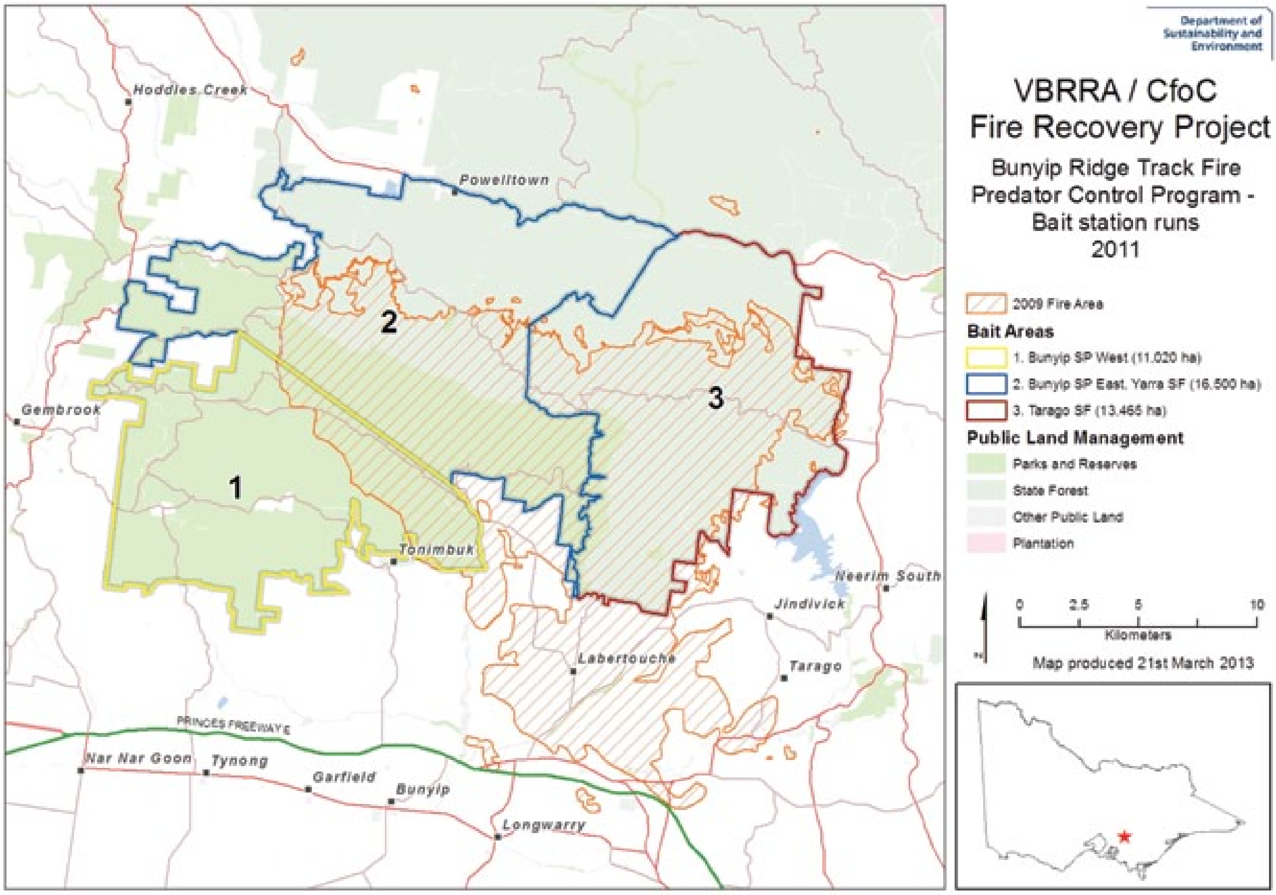


Figure 15. An example of a mandatory sign to notify that 1080 baiting is in progress – Beechworth fire area.

Figure 16. Contractor preparing to bury DeFox bait at a bait station in the Beechworth fire area.

3.3 Field implementation results

Bait stations

The fox control baiting program ran across the four selected fire areas with the following results:

- 1,467 bait stations were established (Table 4) and serviced across 295,985 ha.
- 3,094 bait takes were recorded from a total of 15,092 baits laid (Table 4).

Bait take

A reduction in rate of bait take is expected if predator numbers decline over time.

Bait take data from each of the four areas was standardised to bait take per bait station per week to determine rate of change of bait take and to provide a comparison across treatment areas (Figure 17).

Bait take data used is 'all baits taken'. The attribution of bait takes to Red Fox was inconsistent within and across areas so was not used to measure change in rate of take. For example, in Bunyip fire area all bait takes were allocated to either Dog (wild dogs inhabit the forested areas) or Fox. Percentage of baits taken that were attributed to Red Fox ranged from 61% to 73% across three pulses with an average of 73%. At Tyers-Thompson fire area, bait takes attributed to Red Fox averaged 52%, with 32% attributed to Dogs and 16% to other or unknown species. Most (98%) of bait takes were attributed to Red Fox at Beechworth and none to Dogs, although Dog footprints were noted near bait stations. No species were allocated for part of the program.

Rate of bait take, graphed in Figure 17, shows that there was no clear decrease in rate of bait take during the baiting program across the areas treated.

Table 4. Fox baiting program on-ground results October 2010 to December 2011.

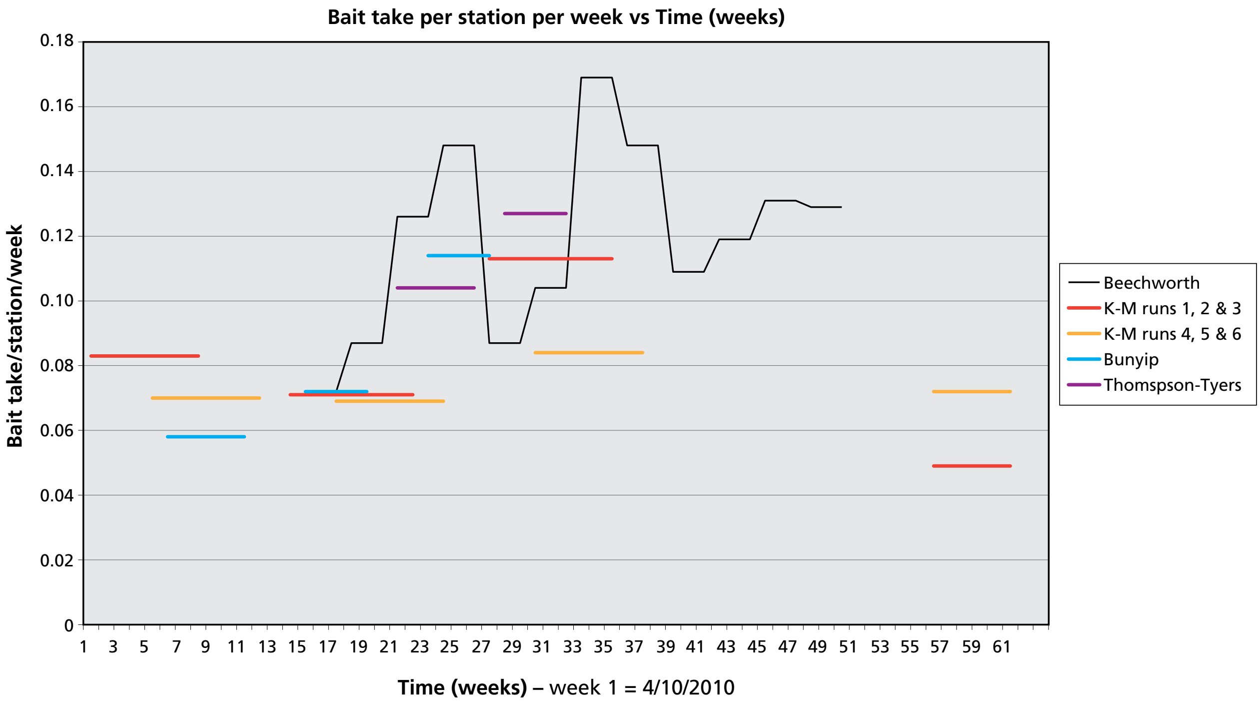
Bushfire-affected Area	Total Area treated (hectares)	Bait stations	Total number baits laid	Total number of baits taken
Beechworth-Library Road	4200	60	732	255
Kilmore East-Murrindindi Complex *	153,000	866 #	11,431	2,074
Bunyip Ridge **	40,985	460	2,718	634
East Tyers-Thomson	30,000	150	211	131
TOTAL	228,185	1,536	15,092	3,094

* This area included Yarra Ranges and Lake Eildon National Parks, Cathedral Range State Park; Big River, Marysville, Rubicon, Toolangi, Paul's Range and Yarra State Forest and Melbourne Water's closed catchments of Maroondah, Cement Creek, O'Shannassy, Armstrong and Upper Yarra as well as the Sugarloaf Pipeline.

** This area included: Bunyip State Park, Kurth Kiln Regional Park, Yarra and Tarago State Forests. Total area was broken down into three areas – Area 1 – 11,020ha, Area 2 – 16,500ha and Area 3 – 13,465ha.

\# Bait stations were re-established for each pulse treatment and were placed at or near the previous location.

Figure 17. Results for bait take per station per week vs time across treated areas. Bait takes are for all baits taken which includes take by foxes, dogs and other species.



Employment

The project engaged local contractors to deliver the field component of the project. Twenty one contractors and staff were engaged. Local contractors had local knowledge and experience of the terrain and methods required for delivery of the field work. In addition, it was hoped that the employment of local people would be a positive contribution to community recovery in fire affected areas.

Communication and community engagement

The project contained plans for communication and community engagement. Elements of the plan included:

Neighbour notification – mandatory neighbour notification forms were mailed out and public notices were also placed in local newspapers.

Media articles – were prepared and sent to regional and local newspapers. Articles on the Beechworth program were run in the Border Mail, The Ovens and Murray Advertiser and The Country News. See Appendix 4 for an example of a Media Release.

Radio – coverage was obtained in the Beechworth fire area.

Community consultation – in the Bunyip fire area, community consultation was undertaken in two areas half way through the program. This resulted in changes to baiting areas, as the original sites were very close to a rural community. These changes assisted in increased protection of domestic animals that led to greater respect from local residents for the baiting program. In the Beechworth fire area, all the Landcare Groups and Wildlife Shelters were informed of the program and they were all supportive of the project. In Stanley (Beechworth area), baits were removed for a three week period over the Christmas/New Year period to accommodate the influx of tourists into the area. This resulted in the program receiving positive feedback from the community of Stanley.

A number of other community engagement activities were held as part of the overall fire recovery program that included information on the fox control program. They included various group presentations, YMCA youth days, a music festival, fire recovery meetings and a tour by a Catchment Management Authority board.

Interagency liaison and contractor communication – due to the broad geographical scope and cross-tenure nature of the program, establishing and maintaining good inter-agency communication channels was vital to the smooth running of the program. Within each project area communication channels were well established and maintained between PV staff and relevant staff in DSE, MW, DPI, local shires, catchment management authorities, etc. This provided for a good two way flow of information regarding site access, program requirements and successes, local knowledge, use of equipment etc. In one project area, the project officer felt they could have benefitted from more interaction with the other project officers working on the same program in the other fire areas.

Communication was made twice a day with contractors in regards to safety and duty of care, and de-briefs were carried out with contractors at the end of each pulse run. Continual communication with contractors allowed opportunities to adapt the program and discuss methods for continual improvement.

Communication with the public – neighbours and the general public were informed via:

- mail-drops before each pulse containing the required 1080 notification, as well as additional program information sheets and map
- newspaper advertisements advising of the program prior to each pulse; required 1080 signage was placed at all tracks leading into baiting areas; information sheets and maps were placed at strategic locations
- information sheets were handed out to residents, campers, etc. as required. In addition, affected user groups, such as hound hunters, were kept directly informed through their relevant member associations. Most comments on the program were positive and supportive suggesting that the comprehensive approach to communication was successful in informing the public. There was very little public concern received by PV regarding the program

3.4 Field implementation discussion

The impact of baiting on Red Fox numbers is difficult to measure from the data collected from bait stations. Due to the variability of data collected, only data standardised to show bait-take (for all takes regardless of species) per station per week could be used. Section 4.5 discusses results of monitoring changes in Red Fox abundance within a designated area of the Kilmore-Murrindindi fire area using different methods. That monitoring suggests that Red Fox abundance may have increased during the program and gives possible reasons. Likewise, the standardised data from all areas treated is also inconclusive. Change in rate of bait take increased from the beginning of baiting to the end at all except one of five areas (Kilmore-Murrindindi was divided into two treatment areas) (see Figure 17). Only Kilmore-Murrindindi runs 1, 2 & 3 had a lower rate of take on the last pulse compared with the first. At Bunyip and Thompson-Tyers, rate of take increased across the three baiting pulses conducted at each area. Beechworth was baited continuously and the graph shows the variability week to week but the trend was an increase in rate of take from the beginning to the end of baiting. Anecdotal reports in the Beechworth-Library Road fox baiting area suggested that fox sightings declined toward the end of the baiting period and local residents reported that native wildlife numbers appeared to be on the increase (Jack Harrington pers. comm.). However, the rate of bait take over the program actually rose (Figure 17). There may not be a direct correlation between rate of bait take and abundance due to factors such as avoidance behaviour of individual animals and/or bait caching behaviour.

Baiting pulse frequency and duration varied across the treatment areas and the only continuous treatment was at Beechworth with a duration of 36 weeks. Robley (2008) reports that continuous, annual baiting programs showed substantial reductions in bait-take and some pulsed baiting programs also showed overall decline in bait-take. A seasonal baiting program was not able to reduce or maintain a reduced level of bait-take or fox activity from year to year.

Whist this project strategically selected areas for treatment, ideally, it is assumed that the baiting program would have had the greatest effect if the frequency of baiting was more consistent and the duration of baiting was longer. A Red Fox control program which commenced following the fire recovery project (Central Highlands Ark, see section 6), and which overlaps with the Kilmore-Murrindindi fire area treated under this project, has enabled this to occur at this location.

Other control methods (e.g. soft jaw trapping) were employed in some areas (e.g. parts of Bunyip and Kilmore-Murrindindi areas) to control foxes post-fire, but prior to and concurrent with this project. Reliance on a single tactic will have limited success in reducing target species and consideration should be given to alternative tactics to control foxes over large areas and long periods (Robley 2008). It is likely that the effects of this project, in reducing fox numbers and predation pressure on 'at risk' native species during the early stages of vegetation recovery could have been greater if the baiting program had started earlier and run more consistently, for longer and with stronger overlap with other control measures such as shooting and trapping.

Across the four Red Fox control program areas the following issues, that affected the delivery of the program, were identified by field staff and contractors:

Weather conditions – A higher than average rainfall during the 2010/2011 period made access to bait runs difficult and at times impossible. In the Kilmore East-Murrindindi fire area the steep nature of much of the country, and condition of some tracks, required care to be taken in order to limit track damage and to ensure safe travel. In addition, reasonably heavy snowfalls occurred from April through June, further restricting access and burying bait stations. In all program areas the variation in weather conditions (including snow and extreme rain) presented daily challenges that were dealt with as required.

Terrain – In many of the fire areas, the fox control program was executed in mountainous country, which in parts was quite steep, rough and remote. This posed challenges for access, as well as making in-field communications difficult at times. In the Kilmore East-Murrindindi fire area, for OH&S reasons, contractors carried personal locater beacons and texted their time in and out of the bush, as well as planned route, to the program supervisor. Mobile phones and UHF radios were also carried but their use was greatly restricted by the terrain. The track conditions were at times challenging with all contractors experiencing some level of damage to vehicles as well as delay from obstructions such as trees down, rock slides and tracks impassable due to rain or snow.

In planning routes, good local knowledge and/or field reconnaissance was required as maps were inaccurate and some information indicated on maps could not be relied upon (e.g. to still be in existence, open, maintained). The presence of log truck traffic on many roads and tracks leading to, from and through much of the baiting area, was also an issue of concern for safe travel that was only partly alleviated by defensive driving and UHF communications with the log truck drivers.

Track closures – Track closures due to logging activities and scheduled road works occurred during the course of the program. These closures required flexibility in route planning and had the potential to result in an inability to cover all areas evenly and require more time to complete runs due to less circuitous routes. Between late Autumn and late Spring most Melbourne Water catchment roads are permanently closed to all vehicles by way of concrete barriers. This delayed works during this period and required additional negotiation with land managers to maintain access as well as modified routes. Other seasonal track closures (typically June to November) also needed to be considered in program and route planning.

Fuel reduction burns – A number of fuel reduction burns were scheduled to occur in the baiting areas. These had the potential to disrupt the program in terms of access, routes and animal behaviour, as well as considering contractor safety issues. In the Kilmore East-Murrindindi fire area only one burn took place because of the wet conditions.

Sand pad monitoring – In the Kilmore East-Murrindindi fire area the wet conditions had a major impact on sand pad monitoring. Contractors were less able to accurately identify species' prints in rain-affected sand. Target animal behaviour may also have been influenced by the wet conditions.

Public land user groups – Consideration and mitigation of the potential impact of the baiting program on various public land user groups was an important consideration in the planning and execution of the program. A key issue was the presence of domestic dogs being walked, taken camping or used as scent trailing hounds in many areas of State Forest where the baiting programs took place.

Domestic dogs – In the Kilmore East-Murrindindi fire area there was one official report of a domestic dog death potentially linked to the program. However, a subsequent Department of Primary Industries (DPI) investigation concluded that 1080 bait-take was highly unlikely to have been the cause of death and that in all ways the program was highly compliant with required processes. In the Bunyip fire area, the response to a suspected domestic dog bait-take was actioned quickly and thoroughly and the dog survived. The cause of the dog's illness was not established but it is doubtful that a poison bait was taken by the dog.

The comprehensive approach to communications, along with care in bait placement (large buffer from campsites, scheduling program around busy periods, etc), helped to alleviate the potential risks to domestic pets of other user groups.

Some of the areas of public land where the fox control program occurred are popular areas for deer hunting (both stalking and hound hunting). In the East Tyres/Thomson fire area, Parks Victoria was proactive in notifying the Australian Deer Association (via their Gippsland branch) and the Victorian Hound Hunting Association. The Australian Deer Association was very happy that they were included in the planning and were able to distribute maps and information to their members. Hunters were directed to areas not being targeted by the project.

Time constraints – In most of the fire areas, the length of time taken to obtain the necessary approvals and documentation caused delays to the start of the baiting program. In the Beechworth fire area, the delays proved frustrating for agency staff and the contractors who had begun mapping and GPSing the bait station sites as early as two months before baits could be laid.

The fox baiting program required a substantial amount of time for planning and set up in each of the four fire areas. Delays in staff coming on board, and the amount of pre-planning time required, delayed the commencement of the program in some areas.

Seasonal issues and the identification of risk – A continuous nine month program meant that it operated across each climatic season. This has implications for weather, fire risk, animal behaviour, public presence/use, baiting effectiveness and encountering other potential risk factors such as snakebite and dangers due to heat or ice and snow. Such issues are clearly out of direct control, but must be considered in Risk Management plans and contingencies for these risk factors identified in the planning and delivery of the program.

Length of the program – As there were delays to the start of the program, the overall length of the baiting program (average of nine months) was too short.

4 Monitoring the effectiveness of the program

4.1 Introduction

In developing the monitoring protocols to evaluate the objectives and outcomes listed above, information was collected and analysed from a series of existing projects — Glenelg Ark assessments of detection rates of various native species undertaken by ARI, a pilot trial undertaken in East Gippsland for the Southern Ark project, work undertaken in the Red Fox Adaptive Management Experiment (Robley and Wright 2003), and work undertaken by ARI in East Gippsland on Project Deliverance (1998–2003).

Based on a series of meetings and discussions with the Predator Project Control Board and regional land management agencies (DSE, PV, Melbourne Water), the monitoring program comprised three broad components, as described in the following sections:

1. Measuring changes in Red Fox populations
2. Measuring differences in Red Fox diet pre and post baiting
3. Measuring changes in native species occurrence

Effective monitoring needs to occur over a longer time frame than the fire recovery funding permitted and to commence immediately after a fire event. Given the short timeframe (effectively 12 months) for activities before the project reporting timeframe expired and the lag-time between the fire event and the commencement of monitoring (19–20 months), the monitoring and evaluation program for measuring changes in native species was further broken down to assess:

- The occurrence and distribution of fauna prey species in the fire-affected areas
- The immediate impact of the reduction in Red Fox abundance on native species
- Collection of baseline data for future monitoring activities.

4.2 Monitoring methods

4.2.2 Measuring changes in Red Fox populations

Monitoring the reduction in Red Foxes resulting from a Red Fox management program is best achieved through the comparison of population estimates, either indices of abundance or some direct measure of abundance (Saunders *et al.* 1995). Estimates of abundance derived from genotyping individual Red Foxes from DNA recovered from scats were undertaken before and after the control program.

Scats were collected from 55 kilometres of tracks in the Kilmore-Murrindindi fire area (Figure 10) and roads within the study area one week prior to, and one week following, the initial eight week baiting program. Pre-baiting scat collection was undertaken by two teams each of two people. A team walked down a track scanning from the middle to the outer edge of the track for scats. All predator scats were collected regardless of their condition and the location of each scat was recorded using hand held GPS. A photograph of each scat was also taken in situ and a visual assessment made of the fire severity history of the location. Scats were assigned to a burn category from one to four (Table 5). This table is a simplified version of Table 2 (p14) used in the SDM modelling procedure.

Table 5. Four burn categories of fire intensity used to assess distribution of native species across the study area.

Fire Severity Class	Severity Type	Description
1	100% Burnt	100% of vegetation is burnt An intense wildfire with complete vegetation burn
2	Severe scorch	60–100% of vegetation scorched, some vegetation burnt An intense understorey fire with widespread vegetation scorch
3	Moderate scorch	30–60% of vegetation is scorched A variable intensity of fire ranging from a light ground burn with minimal scorch to an intense understorey fire with widespread vegetation scorch
4	Light scorch	0–30% vegetation scorch A light ground burn with isolated patches of intense understorey fire and unburnt areas

Post-baiting scat collection was undertaken by two teams of scat detection dogs from the Tasmanian Red Fox Eradication Task Force. A dog and handler walked a section of track and all Red Fox positive scats encountered were collected, their location recorded and a photograph taken. A single dog would be worked for 30 min and then the second dog in that team would commence searching (Figure 18). Post-baiting scat searches were undertaken over the same tracks and roads as the pre-baiting searches.

As in live-trapping methods, population abundances can be determined by non-invasive sampling such as faecal genotyping using capture-recapture methods or by directly counting the number of individuals, the difference being that unique genotypes rather than live-marked animals are recorded (Lettink and Armstrong 2003; Lukacs and Burnham 2005; Prugh *et al.* 2005). Capture-recapture using DNA obtained from Red Fox scats has been undertaken in East Gippsland (Diment 2010) and from trapped hair for estimating Grizzly Bear (*Ursus arctos*) and Black Bear (*Ursus americanus*) abundance in British Columbia and Alberta (Woods *et al.* 1999; Romain-Bondi *et al*. 2004; Wasser *et al.* 2004).

Mark–recapture models can be applied to closed or open populations (Lettink and Armstrong 2003). Most faecal genotyping studies have used closed-population models using the Lincoln-Petersen estimator, which assumes a constant population during the sampling period (e.g. Kohn *et al.* 1999; Harrison *et al.* 2002; Frantz *et al.* 2003; Wasser *et al.* 2004). Although more difficult because population parameters such as births, deaths, immigration or emigration must be taken into account (Lettink and Armstrong 2003), faecal mark–recapture sampling for open populations has also been carried out. Prugh *et al.* (2005) evaluated this approach by sampling a wolf population in Alaska over a three-year period and concluded that faecal genotyping is an effective approach for monitoring populations over a longer time scale. For full details see MacDonald and Sarre (2011).

4.2.3 Capture rates for Red Foxes pre and post predator control

Pre and post fox control heat-in-motion digital cameras (ScoutGuard, SG550V; HCO, Norcross, Georgia, USA) were set for 21 days to assess changes in camera capture rates of Red Foxes. The number of independent images of Red Foxes per 24 hours recorded for each of the four burn categories (Table 5) was used to assess changes in Red Fox activity in relation to fire intensity. The hypothesis that observations were equally distributed across the four burn categories in the pre- and post-control survey period was tested using a chi-square test for goodness-of-fit. Where observations were below five per cell, we either grouped observations or removed them from the analysis. In all tests we applied Yates' correction (Zar 1999).

Figure 18. Tasmanian Red Fox scat collecting team. Handler Olivia Barnard with Tommy and Buddy, and Handler David Cunningham with Bluey and Orange.

4.2.4 Measuring Red Fox diet pre and post baiting

A random selection of eighty scats that were collected for assessment of changes in abundance of Red Foxes was sent for diet analysis by B. Triggs. The proportion of each individual prey item from each scat was recorded and assigned to a burn category.

4.3 Measuring changes in native species populations

4.3.1 Camera capture rate

A pre-baiting and post-baiting survey of native ground-dwelling animal species was undertaken using remotely activated digital cameras set at 40 locations each over a 37 day period. Two camera types were used. Pixcontroller cameras (Pixcontroller Inc., Export, Pennsylvania, USA) which take white flash colour images and ScoutGuard (SG550V; HCO, Norcross, Georgia, USA) which take colour daytime and infrared night-time images. Night-time infrared images reduce the ability to identify small mammals. We differentiated small and intermediate-sized mammals based on relative body size and, where possible, head shape and tail length (e.g. Antechinus <100 mm body length and Bush Rat between 100 mm and 200 mm body length). The feeder stations at each location provided a known scale against which we could determine relative body size (Figure 19). Both cameras recorded the date and time when images were collected.

At sites with ScoutGuard cameras, a feeding station was filled with a mixture of dog kibble (Artimis Pty Ltd, Melbourne) and pistachio essence, and placed 1.5 m in front of a camera. This feeder station was used in an attempt to maximise the time small and intermediate-sized mammals spent at a site to aid in identification. Sites with PixController cameras had a lure of pistachio essence and flax oil soaked in oil absorbent cloth (Matt Spill GP-Grade, All Trade Industrial Supplies, Melbourne) suspended in a tea-infuser inside a small wire cage, attached to a 1.5 m stake, 2 m from a camera (front cover image). Species were identified from the images obtained and captures per 100 camera trap nights used to assess differences before and after control.

4.3.2 Changes in site occupancy of native species

In addition to camera capture rate, we used site occupancy (the proportion of a monitoring area that is occupied) to assess changes in species at risk from Red Fox predation over the short-term. The term 'occupancy' is used here to mean the proportion of sampling units (the areas treated for Red Fox control) that contain the target species at a given point in time.

To estimate the probability a site is occupied by a species of interest, we used the modelling approach developed by MacKenzie *et al.* (2002). Typically, species are not guaranteed to be detected even when present at a site, hence the naïve estimate of occupancy is given by:

$$\text{Naïve occupancy} = \frac{\text{\# sites where species detected}}{\text{total \# sites surveyed}}$$

This will underestimate the true rate of occupancy. MacKenzie *et al.* (2002) propose that by repeated surveying the sites, the probability of detecting the species can be estimated, which then enables unbiased estimation of occupancy.

We undertook analysis using the software program PRESENCE (version 3.1 Hines 2006). PRESENCE uses maximum likelihood to simultaneously estimate detection probabilities (p) and occupancy (psi) from detection history data and evaluates factors that may influence detection (or occupancy) at a given site. Using the single-season occupancy model (MacKenzie *et al.* 2006), we used the a priori model psi(.), p(.) to determine occupancy rates. The difference in occupancy rate between pre and post-control for each species was calculated. If Red Fox control has a statistically significant, positive effect then the entire 95% credible interval (CI) will be above zero. If the treatment has a statistically significant, negative effect then the entire 95% CI will be below zero. Where the 95% CI includes zero, no conclusion can be made regarding the statistical significance of treatment.

Figure 19. Example of a small and intermediate-sized mammal captured by remote camera.

a) small mammal, <100 mm body length, and b) a intermediate-sized mammal, between 100 mm and 200 mm head–body length, most likely an Antechinus *Antechinus* sp. and a Bush Rat *Rattus fuscipes* respectively.

a)

b)

4.4 Monitoring results

4.4.1 Changes in Red Fox abundance

DNA identification and microsatellite profiling of Red Fox scats pre and post-Red Fox control

Prior to Red Fox baiting, 87 predator scats were collected from 55 kilometres of track by two teams of two people between 27 and 30 September 2010 (Figure 20). Scats were collected regardless of their condition, which varied considerably from very fresh to weathered and degraded (Figure 21). Post-baiting, we collected 172 scats using the dog teams between 30 November and 4 December 2010 from the same tracks as in the pre-baiting surveys. Eighty scats were considered to be in a condition suitable to attempt DNA extraction (e.g. scats a, b and c but not d in Figure 21).

Figure 20. Location of scat collection transects during the pre- and post-Red Fox control surveys in September and November/ December 2010.

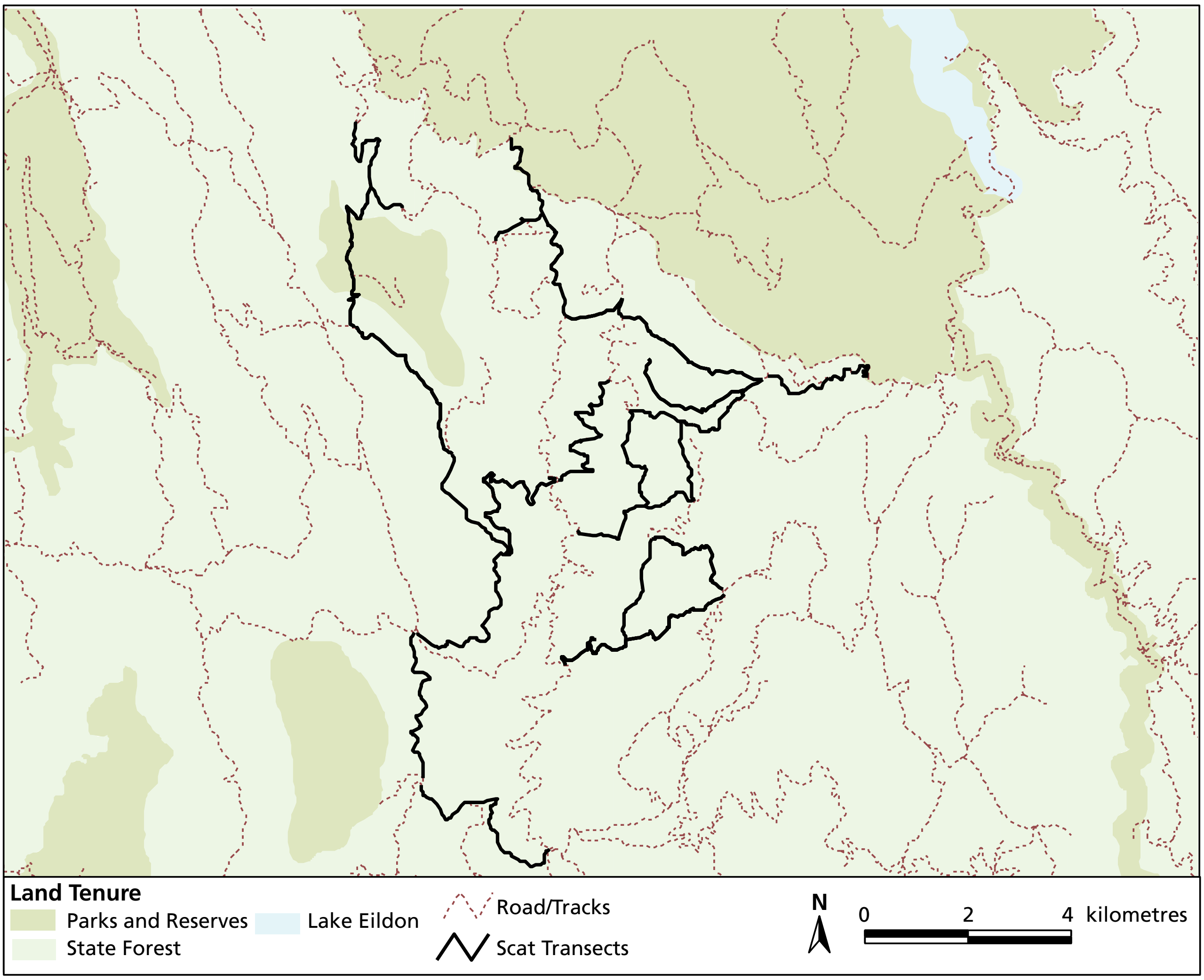
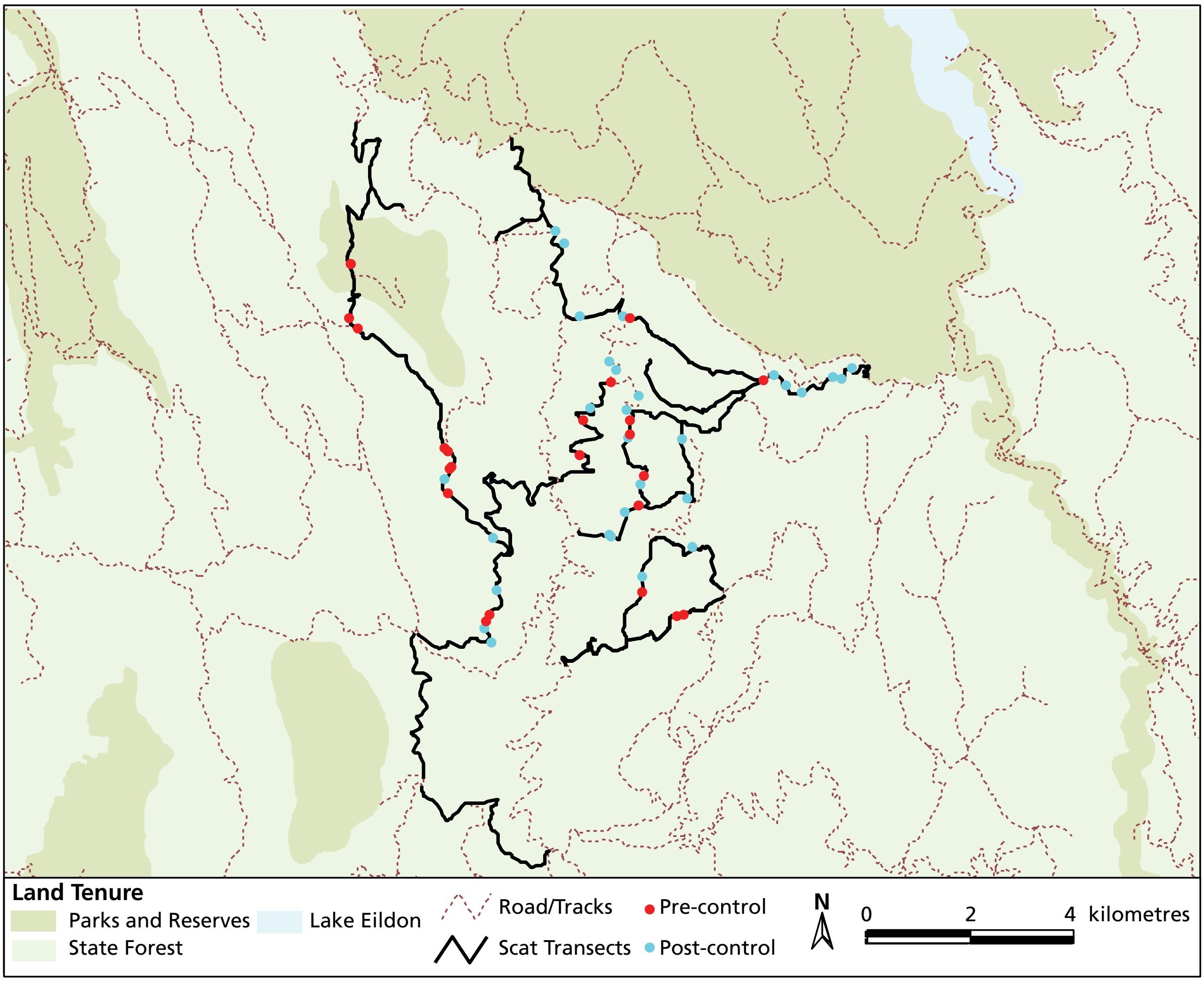


Figure 21. Predator scats collected showing vary degrees of decomposition
a) fresh, b) dried, c) washed out, and d) degraded.

Of the 80 scats collected and sent for DNA testing, only 79 had sufficient DNA material for assessment: 43 scats from the pre-control sample and 36 scats from the post-control sample. Of those, 24 scats from the pre-control sample and 31 scats from the post-control sample had sufficient quality and quantity material to successfully identify Red Fox DNA (Figure 22). Mammalian DNA, but not Red Fox DNA, was detected from a further 24 of the 79 scats, suggesting that these originate from other mammalian carnivores (i.e. wild dogs or feral cats).

Figure 22. Location of Red Fox positive scats pre and post control.



Individual DNA profiling was attempted for all 55 scats found to be positive for Red Fox DNA, using 11 microsatellite loci and a sex (Y-specific) marker. Six replicate genotyping reactions were set up for each scat.

Twenty-two scats were found to contain male DNA, ten scats were scored as female and sex could not be determined in the remaining scats. Ten microsatellite loci were polymorphic in the samples tested, although the number of alleles observed (2–7 alleles per polymorphic locus) was relatively low.

Microsatellite genotyping success was mixed, with good amplification from some scats but poor or no amplification from others. Genotypes were scored using two sets of criteria: 'strict' criteria designed to minimise the effect of genotyping errors and 'relaxed' criteria designed to maximise the available data given the variable genotyping success observed. Population genetic and identity analyses were conducted using both of these datasets.

Analyses of genetic differentiation between the pre and post control samples indicate that all scats analysed should be treated as originating from a single genetic population.

Five sets of scats with matching or near-matching genotypes, which may originate from the same or closely related Red Foxes, were identified. Identity analyses indicate that in at least two cases, pairs of scats collected in the pre- and post-control samples originated from the same individual Red Fox. That is to say, at least two Red Foxes present before baiting, were still present post-baiting.

Low quantity and quality of DNA in many of the scats resulted in the low sample size of individually identified Red Foxes. This prevented mark–recapture analysis or analysis to investigate the density of Red Foxes pre and post control being conducted.

Of the five individual Red Foxes identified (four male and one female), four were located in the pre control survey, and of these two were re-discovered during the post baiting phase. One of the five Red Foxes was only found in the post control phase.

Use of Burn Categories

Low sample size prevented statistical analysis in the pre-control survey. There were zero captures in the 100% Burnt and Severe Scorch categories and observations of Red Foxes in the Moderate and Light Scorch categories did not differ from that expected based on the proportion of camera trap nights. The fact that no observations were made in the 100% Burnt and Severe Scorch categories suggests that use in these categories was lower than in the Moderate and Light Scorch categories.

In the post-control survey there were sufficient observations to test across all four burn categories. We observed more Red Fox captures in the Severe Scorch and less in the Moderate Scorch than would be expected based on the proportion of camera trap nights (X^2 =12.3481, df=3, p = 0.006).

4.4.2 Food items in Red Fox scats

The dietary composition of 80 scats from the pre and post-baiting surveys was analysed. The proportion of prey items in each scat was identified (Figure 23). The most common item was mammalian, comprising *Trichosurus sp*., (42%) most likely Mountain Brushtail Possum (*T. cunninghami)*, followed by Swamp Wallaby (*Wallabia bicolor*; 14%) and Rabbit (*Oryctolagus cuniculus;* 11%). There was a trend towards an increase in insects and a decrease in birds in the post-control period.

Within the mammalian food items, there was a shift in the composition. In the pre-baiting period, Red Fox diet comprised 12 species including House Mouse (*Mus musculus*), Eastern Grey Kangaroo (*Macropus giganteus*), Feathertail Glider (*Acrobates pygmaeus*), Eastern Pygmy-possum (*Cercartetus nanus*), Dusky Antechinus (*Antechinus swainsonii*) and Swamp Rat (*Rattus lutreolus*), which did not appear in the post-control diet. In the post-baiting period, Red Fox diet comprised nine species. The major food items in the post-control samples were *Trichosurus spp.*, European Rabbit (*Oryctolagus cuniculus*) and Swamp Wallaby (*Wallabia bicolor*).

The percentage of food items found in scats (pre and post-control combined) in proportion to the number of scats collected in each burn class is shown in Figure 24. Mammals were slightly more common in the Moderate Scorch class whilst birds were slightly more common in the Light Scorch class. Insects decreased as a food item as fire intensity decreased, while plant material was greatest in the least intensely burnt areas.

Changes in pre and post control habitat use in relation to fire intensity

Results of the chi-square test indicated that the frequency of Red Fox scats collected across the fire altered landscape pre-control were made in proportion to the sampling effort within each of the fire intensity categories (X^2 = 9.0684, df = 3, p = 0.03). That is, there was no difference in the presence of Red Foxes across the fire landscape. Post-control, Red Foxes used the landscape differently across the four fire severity classes (X^2 = 12.35, df = 3, p = 0.006). Red Foxes were observed more in Severely Burnt patches and less in Moderately Burnt patches than expected.

Figure 23. Percentage of food items in Red Fox scats pre- and post-control.

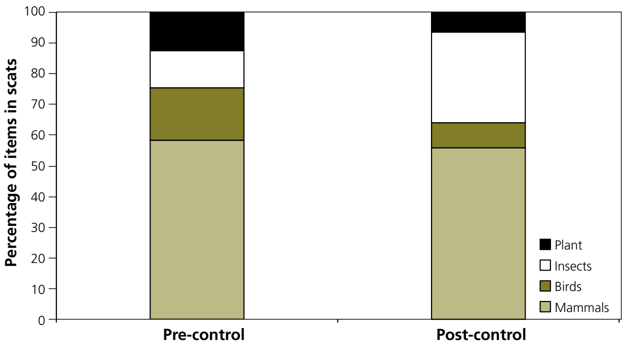
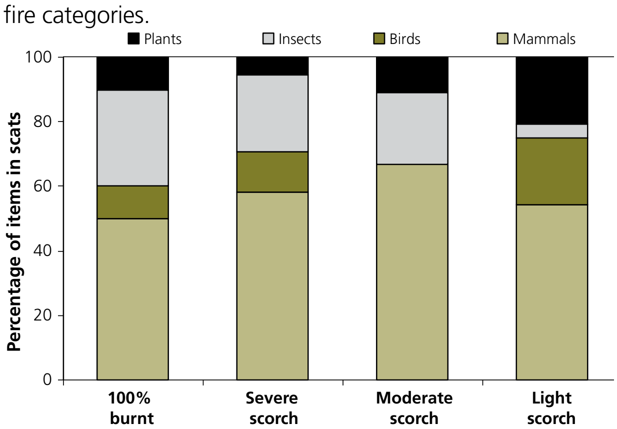


Figure 24. Percentage of food items in Red Fox scats across fire categories.



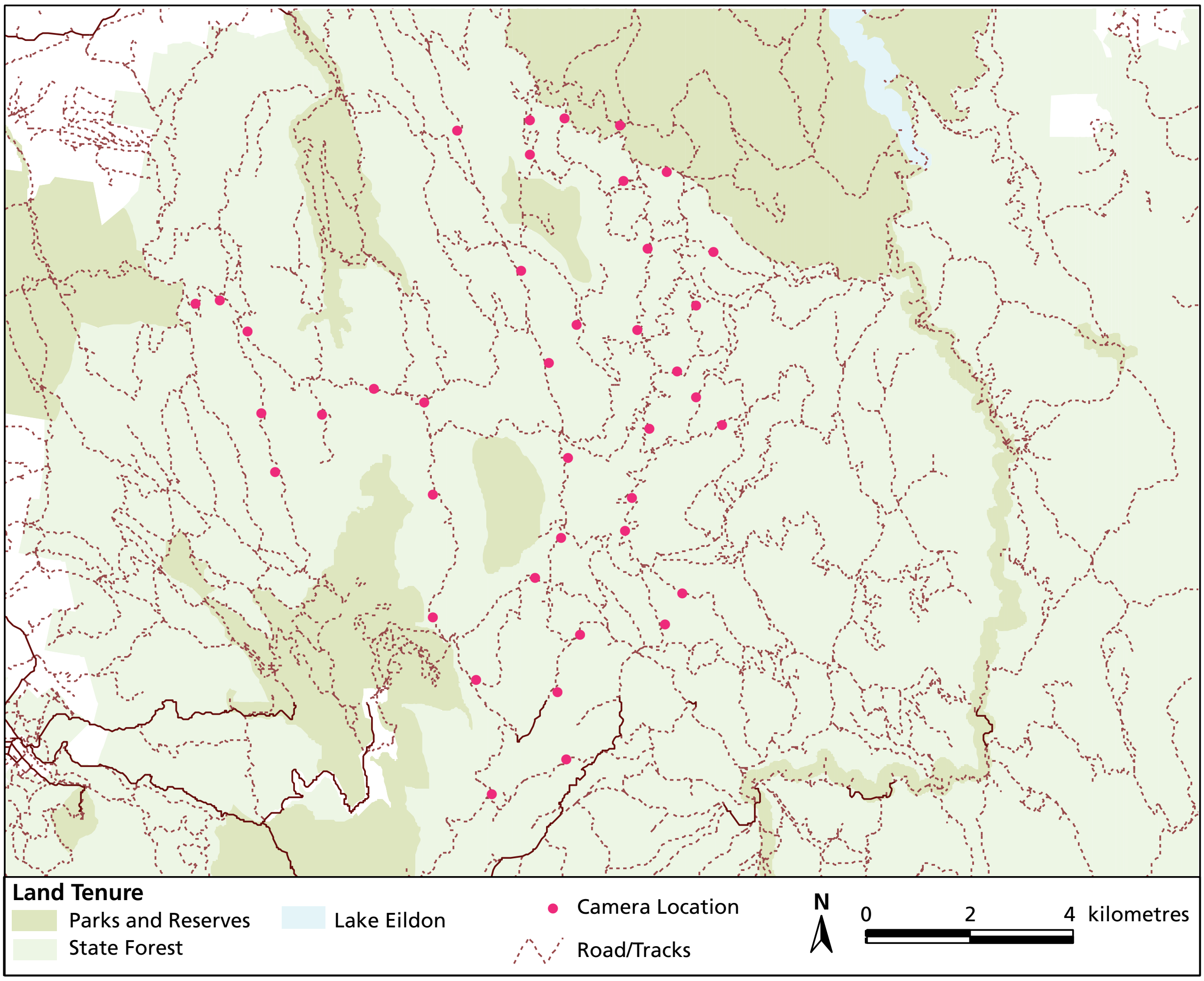
4.4.3 Native species response

Presence and distribution of native species

The influence of burn category and fox control on the abundance and occupancy rate of species captured on remotely activated digital cameras, using captures/100 trap nights and occupancy estimation respectively, was investigated. For the assessment of the influence of burn category on the distribution of species the pre-Red Fox control camera survey data only was used. This was to provide baseline data for later comparisons of change through time associated with a) fox control and b) post-fire habitat change as part of any future long-term monitoring program. In the assessment of occupancy related to fox control, both the combined Pixcontroller/ScoutGuard pre-control data and the ScoutGuard only post-control data was used.

Pre Red Fox control, 39 Pixcontroller and 39 ScoutGuard cameras were set between 31 August 2010 and 8 October 2010 for an average of 26 days ± 2 days. Of these, five ScoutGuard and eight Pixcontroller cameras completely failed. Post Red Fox control, 39 ScoutGuard cameras were deployed to the same locations as the pre-control period between 15 November and 15 December 2010 for an average of 24 days ± 5 days. Of these, 10 cameras completely failed before the sample period was complete. Figure 25 indicates the general location of cameras in this study. In the pre Red Fox control survey, ScoutGuard and Pixcontroller cameras were placed on opposite sides of a track and separated by a minimum of 500 metres. In the post Red Fox control survey, ScoutGuard cameras were placed in the same location as in the pre Red Fox control survey.

Figure 25. Location of ScoutGuard digital cameras used in the pre and post-baiting survey.



We recorded 190 camera-captures of 13 species across the four fire categories shown in Table 8. In proportion to the camera/trap nights in each burn category, the majority of captures were within the Severe Scorch category, with 11 of the 13 species being captured most frequently in this category (Table 9; Figure 26).

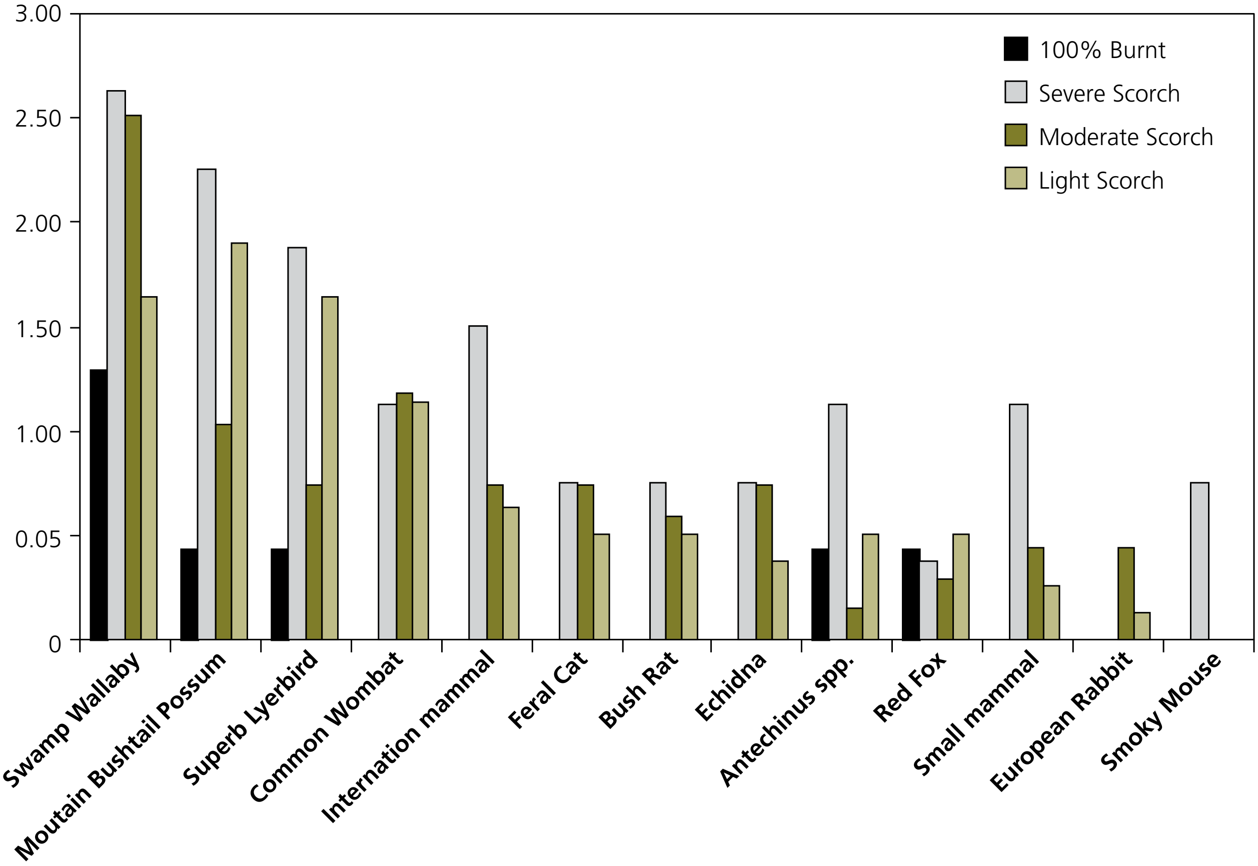
Only four species were recorded in all four burn categories, and only the Red Fox was recorded in near equal proportion across all four categories (albeit at a low rate). This suggests that Red Foxes were at least widespread, if not common across the site. Camera capture rates for Swamp Wallabies were highest in the Severe and Moderate categories, Mountain Brushtail Possums and Superb Lyrebirds were more frequently captured in Severe Scorch and Light Scorch areas. Small mammals, including *Antechinus* spp. and Smoky Mouse were most often captured on cameras in the Severe Scorch category. Echidnas were captured more often in Severely Burnt and Moderate Scorch than any other category, while European Rabbits were found in only two burn categories, and more often in Moderate Scorch areas.

Table 6. Captures per 100 camera trap nights in four burn categories from the pre-Red Fox control ScoutGuard and Pixcontroller camera survey. Captures are the number of individuals per site within a burn category/total number of camera nights within a burn category. For example, in 100 trap nights we expect to capture 1.3 Swamp Wallaby in 100% Burnt areas.

Species Common Name	100% Burnt	Severe Scorch	Moderate Scorch	Light Scorch	Total captures/ 100 camera trap nights
Swamp Wallaby	1.30	2.65	2.53	1.66	2.08
Mountain Brushtail Possum	0.43	2.27	1.04	1.91	1.51
Superb Lyrebird	0.43	1.89	0.74	1.66	1.25
Common Wombat	0.00	1.14	1.19	1.15	1.04
Indeterminate mammal *	0.00	1.52	0.74	0.64	0.73
Feral Cat	0.00	0.76	0.74	0.51	0.57
Bush Rat	0.00	0.76	0.60	0.51	0.52
Echidna	0.00	0.76	0.74	0.38	0.52
Antechinus spp.	0.43	1.14	0.15	0.51	0.47
Red Fox	0.43	0.38	0.30	0.51	0.42
Small mammal *	0.00	1.14	0.45	0.26	0.42
European Rabbit	0.00	0.00	0.45	0.13	0.21
Smoky Mouse	0.00	0.76	0.15	0.00	0.16

*Small mammal, <100 mm body length, and intermediate-sized mammal, between 100 mm and 200 mm head–body length.

Figure 26. Species captures per 100 camera trap nights in four burn categories from the pre Red Fox control ScoutGuard and Pixcontroller combined camera survey.



Site occupancy estimates of native species

As part of the potential long-term monitoring program, occupancy rates for all species that had sufficient data, including introduced predators, were estimated (Table 7). We also assessed the difference in pre- and post-control occupancy estimates to determine the impact of Red Fox control (Figure 27).

Occupancy estimates were determined for all species detected by cameras (combined Pixcontroller/ScoutGuard surveys pre-control and ScoutGuard surveys post-control), with the exception of Echidna, for which there were too few encounters. Pre-control estimates were highest for Common Wombat, Feral Cat and Swamp Wallaby, and lowest for Red Foxes. In the post-control survey, occupancy was highest for Swamp Wallaby and Superb Lyrebird and lowest for small mammals.

Table 7. Occupancy estimates for species detected during pre- and post-Red Fox control survey.

Species	Occupancy	
	Pre-Control (SE)	Post-Control (SE)
Mountain Brushtail Possum	0.352 (0.095)	0.330 (0.092)
Feral Cat	0.524 (0.312)	0.085 (0.062)
Red Fox	0.111 (0.060)	0.173 (0.070)
Intermediate mammals	0.283 (0.080)	0.277 (0.083)
Superb Lyrebird	0.268 (0.094)	0.541 (0.121)
Small mammals	0.253 (0.086)	0.034 (0.034)
Swamp Wallaby	0.497 (0.131)	0.584 (0.123)
Common Wombat	0.552 (0.188)	NA

NB: small mammal, <100 mm body length, and intermediate-sized mammal, between 100 mm and 200 mm head–body length.

There was no change in occupancy for Red Foxes. There was an increase in occupancy rate for Superb Lyrebird, and a substantial decrease in estimates for Feral Cat and small mammals. Estimates for the remaining species remained effectively unchanged.

The probability that there was a significant treatment effect is shown in Table 8. There was no detectable positive effect of control on Red Foxes. There was a significant positive effect of treatment on Superb Lyrebird, and a significant negative effect on small mammals. There was a substantial, but not statistically significant, decrease in Feral Cat post-control.

4.5 Monitoring discussion

Red Foxes were monitored pre and post the initial eight-week 1080 poison baiting program. The overall baiting program covered a wider area than that where the monitoring program was implemented. As such, Parks Victoria had several contractors implementing the baiting program. An unforeseen result of this was that more than one contractor was operating over the monitoring area. Despite Parks Victoria's efforts to standardise the way in which contractors collected and reported the results of the baiting operation, inconsistencies made collation of the data problematic.

Figure 27. Effect size of Red Fox control on occupancy estimates pre and post Red Fox control. Bars are upper and lower confidence limits.

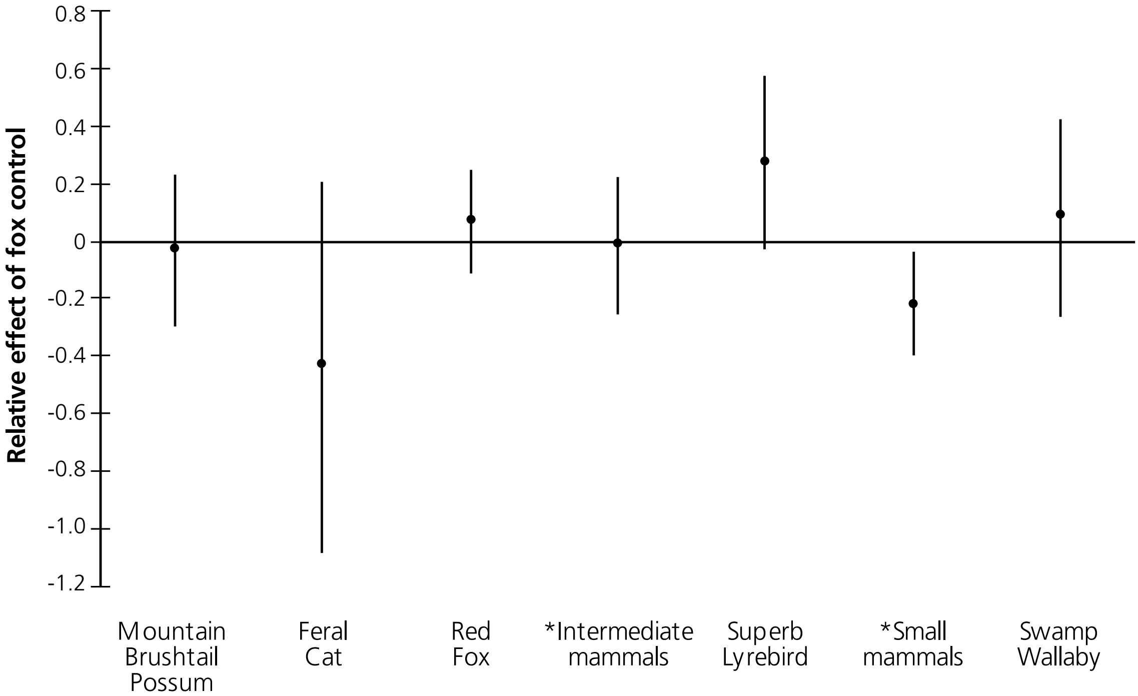


Table 8. Probability of a significant difference between pre- and post-control occupancy estimates. For example there is a 97% probability that the confidence intervals for Superb Lyrebird do not overlap with zero, i.e., p = 0.03.

	Mountain Brushtail Possum	Feral Cat	Red Fox	Intermediate mammals	Superb Lyrebird	Small mammals	Swamp Wallaby
Probability	0.41	0.08	0.76	0.49	0.97	0.01	0.70

Non-invasive genetic approaches were successfully applied to identify 55 scats that were positive for Red Fox DNA and to identify the sex of the animal of 32 of these scats. Microsatellite genotyping success was varied, but was able to obtain usable individual profiles for up to 20 scat samples, using strict or relaxed scoring criteria. Population genetic analyses indicate that overall genetic diversity was fairly low and that the pre and post-control samples should be treated as originating from a single genetic population (i.e. that there is no significant genetic differentiation between samples collected before Red Fox control measures were conducted and those collected afterwards). This may indicate that the control measures did not significantly reduce the Red Fox population present in the area studied, but it is also possible that this area is part of a larger genetic population and that new migrants post-control cannot be distinguished from individuals present in the area pre-control. Further population genetic studies would be needed to determine this. Identity analyses indicate that some of the genotypes observed were sampled multiple times, suggesting that in some cases two or more of the scats analysed were left by the same individual Red Fox. In two instances, scats with matching genotypes were collected pre and post-control, suggesting that at least two individual Red Foxes were present in the study area both before and after the control measures were conducted. However, in a population of closely related animals with low genetic diversity it is likely that different individuals will have similar genotypes, so more information on the size and the genetic structure of the Red Fox population of the wider area, which is a potential source of migrants to the study area, would be useful to determine the likelihood of these different possibilities.

Due to the low sample size of individually identified Red Foxes resulting from low quality and quantity of DNA material in the samples collected, mark–recapture analysis or analysis to investigate the density of Red Fox's pre- and post-control was unable to be conducted. Thus, it is not possible to draw any robust conclusions about the effectiveness of the Red Fox control program.

However, the area covered by the scat sampling (54 km^2) would be capable of holding between 10 and 97 Red Foxes based on density estimates of 0.2 / km^2 in dry sclerophyll forest in coastal NSW (Newsome and Catling 1992) and 1.8 / km^2 in sub-alpine eastern NSW (Saunders et al. 1995). Our surveys were undertaken 18 months post-fire and the impact on survival and recolonisation is unknown for Red Foxes. It may be that prey densities have recovered but the Red Fox population is lagging behind. Identification of individual Red Foxes from scats was hampered by a lack of quality DNA material extracted from scats. It is likely that there are more than five individuals in the study area.

In future control operations broader sampling of the wider pre-control population would be advisable, as would the use of scat detector dogs to firstly clear an area of scats prior to the pre and post-control sampling. It is likely that scats missed by the human survey teams in the pre-control survey were discovered by the dog survey teams in the post-control period. Given the short timeframe for implementing the baiting and monitoring programs it was not possible to engage the dog teams in the initial survey or to sweep the areas clan prior to the collection surveys.

Camera trapping rates indicated that Red Foxes increased following the initial eight-week baiting program. In the post-control survey, juvenile Red Foxes were recorded at a number of sites, while in the pre-control period none where recorded. Births of Red Foxes peak in August/September in temperate parts of Australia, with dispersal of independent animals occurring through summer (Saunders *et al.* 1995). This would be around the time of the second survey (December). It is possible that the control program removed a number of adult Red Foxes and that the void was filled by dispersing young from within and surrounding areas. Saunders *et al.* (2007) note that Red Foxes are able to quickly reinvade areas that have been baited. The increase in camera trapping rates could be a measure of the rapid rate of reinvasion from surrounding 'floater' Red Foxes. A third possibility is that the baiting program removed some individual 'mates' and the remaining Red Foxes were exploring a wider area either in search of missing individuals or exploring 'vacant' territory (Saunders *et al.* 2007). This highlights the importance of follow up control within a short period of time, the need for constant control activities and the need for follow up and long-term monitoring. It is also possible that few if any foxes were killed by the control program.

The monitoring and evaluation program was implemented 18 months post-fire. It is not known how habitat structure has changed in the time since the fire passed through the landscape. Four fire intensity classes based on immediate post-fire remote sensing undertaken by DSE were identified. Red Foxes showed no sign of selecting for habitat based on these classes during the pre-control survey period, but did show some preference for Severely Scorched and a lesser preference for Moderately Scorched habitat than expected during the post control period. However, it is possible that in the intervening time the habitat has recovered to such a degree that the resources required by Red Foxes are now present across these classes and that selection of habitat is being driven by other factors not measured here.

Red Fox scats collected in this study comprised mainly mammalian food items of which Mountain Brushtail Possum, Swamp Wallaby and European Rabbit were the most common. Insects and plants were also common elements. This is consistent with previous studies that have shown that Red Foxes are carnivorous, mainly consuming mammals, but that insects and plant material make up a considerable proportion of their diet (Saunders *et al.* 1995).

Importantly, the proportional composition of dietary items may not be an indicator of the impact Red Foxes are having on native species. Species that were rare in Red Fox scats were Feathertail Glider (*Acrobates pygmaeus*), Sugar Glider (*Petaurus breviceps*), Greater Glider (*Petauroides volans*), Common Ringtail Possum (*Pseudocheirus peregrinus*) and Eastern Pygmy-possum (*Cercartetus nanus;* Near Threatened). None of these species were detected by remote digital cameras as all are primarily arboreal. The scat survey has confirmed the presence of these species in areas that were subject to the 2009 fires. It also provides an indication that post-fire predation in fire impacted habitats may have an important impact of the resilience of ecosystems subjected to fire.

There appeared to be some influence on the distribution of native species in relation to fire intensity. Only five of the 13 recorded species were found in the 100% Burnt habitat, while the majority of captures were within the Severe Scorch category, with 11 of the 13 species being captured most frequently in this category. The most common species in relation to all fire categories were Swamp Wallaby, Mountain Brushtail Possum and Superb Lyrebird. The least widespread species were Smoky Mouse and European Rabbit. Red Foxes were found in nearly equal proportion in all four burn categories suggesting they were widespread, if in low density.

The use of occupancy estimates based on detection of target species at monitoring sites as used in this study is a widely acceptable method for assessing success of biodiversity conservation actions (Mackenzie *et al*. 2006). We have established baseline data that could be used in long-term monitoring. This would require establishing monitoring protocols to detect species at the 40 monitoring stations established throughout the study area. We used digital cameras; however, hair tubes could be used if cameras were not available. While the cost of operating hair tubes and cameras is comparable, the range of species that can be detected by cameras is greater making the use of digital cameras preferable.

The timing of the monitoring sessions for detecting changes in native species occupancy is related to two factors: a) limited understanding of the population dynamics of the target native species, and b) the likely impact of Red Fox predation on those dynamics. If juveniles of native species are more susceptible to predation than adults, recruitment into the population will be low. If this cohort has been preferentially targeted by Red Fox predation then, in theory, there will be more individuals available in the landscape for detection through the years on treated sites and as the population increases so will the sites they occupy. Alternatively, if adults are more vulnerable then reproductive output would be reduced.

One monitoring session was undertaken prior to the initial eight-week baiting phase. While less than ideal, this is all that could be achieved given the implementation timeframe. This data will provide critical information on the starting condition of the monitoring area and lays the foundation for longer-term monitoring. However, it needs to be recognised that this design has significant limitations on the ability to interpret any associations with changes in fox numbers through time.

Unless monitoring and evaluation are recurrent components of management, management will have no capacity to a) justify reinvestment of scarce public conservation funds, b) improve management actions based on reliable information about the effectiveness of previous management actions, and c) maintain community support. Thus, monitoring and evaluation should be seen as a part of management not an imposition or adjunct to it.

5 Recommendations

Preparedness recommendations

This project has contributed to the knowledge and processes that underpin an enhanced response to future fire events.

Strategic planning could be enhanced by developing the data sets and information tools necessary to prepare for future emergency events in which predation may be a significant risk. Forward preparation of mapped locations for priority control of pest animals, with or without a major disturbance, would benefit rapid response to emergencies. It would also enable priority areas for predator control to be targeted prior to the potential negative effects of fire.

Pre fire data on predators and prey populations, and a capacity to rapidly acquire data on predator and prey populations immediately following fire would be beneficial, including the option of using trained dogs for scat collection.

As predation is likely to have its most significant effect immediately following a fire event, early access to funding, even in relatively small amounts, would enhance the capacity for rapid response and more effective outcomes.

Preparation of standard monitoring and recording systems (e.g. for bait take data) and tools, such as smartphone applications, would ensure appropriate and comparative data was being recorded across a wide range of users involved in implementation of predator control programs.

Project recommendations

The following recommendations are made to guide future projects:

Planning – Issues associated with such factors as inclement weather, difficult terrain, poor access and track conditions, fuel reduction burns, animal behaviour etc. need to be factored in when planning future fox control programs. Flexibility should be built into the program to cater for these variables.

Document preparation and timing – In planning future programs, required approvals and documentation (such as the PV/DSE Application to Control Pest Animals documents) should be obtained well beforehand to avoid delaying commencement of a program.

Risk Identification and Management – Due to the remote and rough nature of the program area, contractor and supervisor safety needed careful consideration. Potential risks can be mitigated through the use of well maintained vehicles equipped with UHF and trunk radios, high gain mobile phone antennas, recovery equipment, first aid, personal locator beacons, personal protective equipment, etcetera and by way of communication protocols such as checking in and out of areas by text message and leaving daily route/location details with relevant supervisors and at work centres. These equipment and procedural requirements should be incorporated into job safety documents.

Communications – As Shire mailout lists will not reach all properties, future projects should anticipate the need for additional, hand-delivered, landowner notifications. Additional signage and media would be useful to alert the public to the program and its value. Increased interaction and engagement with user groups and the community prior to a baiting run to ascertain their recreational habits and possibly modify the baiting areas would be beneficial.

Use of bait station cameras – More extensive use of remote cameras at selected bait stations would provide more comprehensive monitoring data, particularly where there is a risk of off-target bait take to identify species potentially affected.

Ongoing fox control – A fox baiting program should be undertaken over an adequate length of time to maximise effectiveness and efficiency of the program. The timeframe could be based on the degree of redevelopment of habitat, which may take 3–5 years depending on vegetation type and site variables.

Suppression of the Red Fox population – Bait take data should be analysed for each round of baiting. Mitchell and Balogh (2009) describe methods for converting bait take data into an index of abundance using frequency/density transformation.

Digital cameras (maximum two per km^2 set for a minimum of 21 days using a predator lure) can also be used to assess trends in occupancy. This approach could also be used to assess trends in occupancy rates of Feral Cat. It would not be appropriate to use digital cameras for assessing changes in native species at the same sites as for introduced predators, as this combination would require luring introduced predators and native species to the same site.

Monitoring changes in predator diet – Continued annual assessment of the proportional composition of Red Fox diet would provide information on the spatial and temporal change in distribution of a range of native species that were not detected by camera survey. Scat collection should occur at the same time and place as in this study.

Monitoring changes in native species – Further interrogation of the model output to identify those species that comprised the overall biodiversity benefit described in the model. This information could be used to better target monitoring methods to those species.

Site occupancy may change over years as populations change. When sites are surveyed between these periods of change, over a number of years, the approach described here can be combined with a robust mark–recapture approach (Pollock *et al*. 1990). Sampling, using digital cameras should be repeated at the same site each year and continued for several years. The change in occupancy rates over years could then be modelled as a function of site colonisation and extinction rates, analogous with birth and death rates in an open-population mark–recapture study, and explanatory variables such has fire history, presence of predators and changes in vegetation structure can be incorporated into the analysis.

While the monitoring and evaluation of selected indicator species has been designed using the best available data, it is strongly recommended that in future, after the first year, the data collected is used to reassess the sampling design and, if necessary, amend the monitoring program.

6 Beyond this project – a postscript

Native species response

Small mammal surveys at Bellell Creek in the Kilmore East-Murrindindi fire area recorded the return of Agile Antechinus *Antechinus agilis* and Dusky Antechinus *Antechinus swainsonii* to the site, albeit in low numbers. These most recent results are encouraging and indicate that the small mammal population at Bellell Creek is only just beginning to recover after the disturbance caused by the Black Saturday bushfires. Surveillance cameras have resulted in the near threatened Eastern Pygmy-possum *Cecartetus nanus* being detected within close proximity to the site. The cameras also detected feral predators in the area and were a valuable survey tool for the program (Biosis Research 2011). These survey results reinforce the importance of continuous and regular predator control.

During 2012 to 2013 there have been numerous sightings and a number of reports of road killed Long-nosed Bandicoots *Perameles nasuta* across much of the area impacted by the 2009 Kilmore-Murrindindi fire. Bandicoots are one of the 'at risk' native species preyed on by Red Foxes. The apparent recovery of this species coincides with good rainfall in 2011–12 and thick fire regrowth which provides cover. Although difficult to measure, this predator control project and the continuing Central Highlands Ark Project (see below) are likely to have contributed.

Central Highlands Ark Project and long-term monitoring

DSE and partner agencies are continuing Red Fox control in the Kilmore-Murrindindi fire area as part of the new CHAP which commenced in 2012 and covers 150,000 hectares. The project is focused on Red Fox control using 1080 baiting. Sustained, regular pulse treatments are being used. The project is currently funded until 2014. The project includes a monitoring component aimed at measuring changes in both Red Fox abundance and the abundance of native species at risk of Red Fox predation.

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Appendix 1 Relative ranking of fauna species considered to be at risk from Red Fox predation

Relative weightings (RW) are the cubed product of weightings previously developed by Robley and Choquenot (2002). Species not included in the site prioritisation analysis are indicated by an asterisk.

Species	RW
Eastern Barred Bandicoot	1.00
Long-footed Potoroo	1.00
Bush Stone Curlew	0.97
Brush-tailed Rock Wallaby	0.94
Long-nosed Potoroo	0.91
Heath Mouse *	0.91
Heath Skink	0.83
Millewa Skink *	0.83
Little Tern	0.78
Hooded Plover	0.78
Common Dunnart	0.78
Long-nosed Bandicoot	0.75
Silky Mouse	0.70
Mallee Ningaui	0.64
Fat-tailed Dunnart	0.64
Southern Brown Bandicoot	0.64
Bardick	0.64
Port Lincoln Snake *	0.64
Plains-wanderer	0.59
Malleefowl	0.57
White-footed Dunnart	0.57
Yellow-footed Antechinus	0.55
Mueller's Skink *	0.55
Magpie Goose	0.53
Brush-tailed Phascogale	0.53
Hooded Scaly-foot	0.53
Samphire Skink	0.53
Alpine She-oak Skink	0.53
Australian Bustard	0.49
Common Wombat	0.49
Water Rat	0.49

Species	RW
Broad-toothed Rat	0.49
New Holland Mouse	0.49
Smoky Mouse (Eastern and Western forms)	0.49
Curl Snake	0.49
Brolga	0.46
Redthroat	0.46
Spot-tailed Quoll	0.46
Paucident Planigale	0.46
Mountain Pygmy-possum	0.46
Diamond Dove	0.44
Glossy Ibis *	0.44
Mitchell's Hopping-mouse	0.44
Red-chested Button-quail	0.41
Red-lored Whistler	0.41
Striated Grasswren	0.41
Short-beaked Echidna	0.41
Common Brushtail Possum	0.41
Beaked Gecko	0.41
Pink-tailed Worm-lizard	0.41
Red-naped Snake	0.41
Corangamite Water Skink	0.41
Eastern Wallaroo *	0.37
Short-tailed Shearwater	0.36
Gull-billed Tern	0.36
Caspian Tern	0.36
Great Egret	0.36
Barking Owl	0.36
Slender-billed Thornbill	0.36
Swamp Antechinus	0.36
Striped Legless Lizard	0.36
Alpine Bog Skink	0.36

Continued next page

Appendix 1 continued

Species	RW
Cape Barren Goose	0.34
Rosenberg's Goanna	0.34
Crested Tern	0.33
Bush Rat	0.33
Australasian Gannet	0.31
Eastern Curlew *	0.31
Ground Parrot	0.31
Rainbow Bee-eater	0.31
Speckled Warbler	0.31
Cattle Egret	0.31
Dusky Antechinus	0.31
Squirrel Glider	0.31
Baillon's Crake	0.29
Fairy Tern	0.29
Turquoise Parrot	0.29
Orange-bellied Parrot	0.29
Eastern Bristlebird	0.29
Mallee Emu-wren	0.29
Agile Antechinus	0.29
Australasian Bittern	0.27
Mountain Brushtail Possum	0.26
Greater Glider	0.26
Lewin's Rail	0.25
Red-necked Wallaby	0.25
Swamp Skink	0.25
Alpine Water Skink	0.25
Carpet Python	0.24
Black-faced Cormorant	0.23
Spotted Bowerbird *	0.23
Diamond Python	0.23
Painted Honeyeater	0.22

Species	RW
King Quail	0.21
Grey-crowned Babbler	0.21
Common Death Adder *	0.21
Lined Earless Dragon	0.21
Grasslands Earless Dragon	0.21
Barking Marsh Frog	0.21
Giant Bullfrog	0.21
Southern Barred Frog *	0.21
Tyler's Toadlet *	0.21
Freckled Duck	0.20
Woodland Blind Snake	0.20
Musk Duck	0.18
Rufous Bristlebird *	0.18
Leadbeaters Possum	0.18
Feathertail Glider	0.18
Little Pygmy-possum	0.18
Tessellated Gecko	0.18
Martin's Toadlet *	0.18
Darter	0.15
Royal Spoonbill	0.15
Intermediate Egret	0.15
Nankeen Night Heron	0.15
Little Bittern	0.15
Square-tailed Kite	0.15
Ground Cuckoo-shrike	0.15
Swamp Rat	0.15
Eastern Water Skink	0.15
Chestnut-rumped Heathwren	0.13
Western Pygmy-possum	0.13
Western Blue-tongued Lizard	0.13
Warty Bell Frog	0.13

Continued next page

Appendix 1 continued

Species	RW
Pied Cormorant	0.11
Painted Snipe *	0.11
Blue-billed Duck	0.11
Common Ringtail Possum	0.11
Yellow-bellied Glider	0.11
Sugar Glider	0.11
Swamp Wallaby	0.11
Baw Baw Frog	0.11
Booroolong Tree Frog *	0.11
Eastern Pygmy-possum	0.10
Large Brown Tree Frog *	0.10
Apostlebird	0.09
Broad-shelled Tortoise	0.09
Giant Burrowing Frog	0.09
Spotted Tree Frog	0.09
Alpine Tree Frog	0.09
Desert Skink	0.07
Bandy Bandy	0.07
Whiskered Tern	0.06
Rugose Toadlet *	0.06
Bynoe's Gecko	0.05

Appendix 2 Percentage of food items in 80 scats collected from the study area

Survey	Common Name	Scientific Name	Composition (%)			
			Mammal	Bird	Insect	Plant
Post-control	Deer	*Cervus* sp.	10		90	
Post-control	Deer	*Cervus* sp.	10		20	
Post-control		no hairs		100		
Post-control		no hairs			100	
Post-control		no hairs			100	
Post-control		no hairs		80	20	
Post-control	European Rabbit	*Oryctolagus cuniculus*	80		10	10
Post-control	European Rabbit	*Oryctolagus cuniculus*	5		95	
Post-control	European Rabbit	*Oryctolagus cuniculus*	80		20	
Post-control	European Rabbit	*Oryctolagus cuniculus*	50		50	
Post-control	European Rabbit	*Oryctolagus cuniculus*	70		30	
Post-control	European Rabbit	*Oryctolagus cuniculus*	90		10	
Post-control	Sugar Glider	*Petaurus breviceps*	60		40	
Post-control	Greater Glider	*Petauroides volans*	100			
Post-control	Greater Glider	*Petauroides volans*	80		10	10
Post-control	Greater Glider	*Petauroides volans*	100			
Post-control	Mountain Brushtail Possum	*Trichosurus cunninghami*	100			
Post-control	Mountain Brushtail Possum	*Trichosurus cunninghami*	100			
Post-control	Echidna	*Tachyglossus aculeatus*	95		5	
Post-control	Possum sp.	*Trichosurus* sp.	100			
Post-control	Possum sp.	*Trichosurus* sp.	100			
Post-control	Possum sp.	*Trichosurus* sp.	20	80		
Post-control	Possum sp.	*Trichosurus* sp.	80	20		
Post-control	Possum sp.	*Trichosurus* sp.	90			10
Post-control	Possum sp.	*Trichosurus* sp.	100			
Post-control	Possum sp.	*Trichosurus* sp.	100			
Post-control	Possum sp.	*Trichosurus* sp.	90		10	
Post-control	Possum sp.	*Trichosurus* sp.	70			30
Post-control	Possum sp.	*Trichosurus* sp.	60		40	
Post-control	Possum sp.	*Trichosurus* sp.	90			
Post-control	Possum sp.	*Trichosurus* sp.				
Post-control	Possum sp.	*Trichosurus* sp.	90		10	
Post-control	Possum sp.	*Trichosurus* sp.	100			
Post-control	Possum sp.	*Trichosurus* sp.	80		20	
Post-control	Common Wombat	*Vombatus ursinus*	100			
Post-control	Black Wallaby	*Wallabia bicolor*	100			
Post-control	Black Wallaby	*Wallabia bicolor*	70			
Post-control	Black Wallaby	*Wallabia bicolor*	100			
Post-control	Black Wallaby	*Wallabia bicolor*	90	10		
Pre-control	Dusky Antechinus	*Antechinus swainsonii*	20			
Pre-control	Dusky Antechinus	*Antechinus swainsonii*	80	10		

Continued next page

Appendix 2 continued

Survey	Common Name	Scientific Name	Composition (%)			
			Mammal	Bird	Insect	Plant
Pre-control	Feathertail Glider	*Acrobates pygmaeus*	80		15	5
Pre-control	Eastern Pygmy-possum	*Cercartetus nanus*	10	90		
Pre-control	Eastern Pygmy-possum	*Cercartetus nanus*	40	60		
Pre-control	House Mouse	*Mus musculus*	80			20
Pre-control	House Mouse	*Mus musculus*	95		5	
Pre-control	Eastern Grey Kangaroo	*Macropus giganteus*	95			5
Pre-control		no hairs		100		
Pre-control		no hairs		100		
Pre-control		no hairs		100		
Pre-control	European Rabbit	*Oryctolagus cuniculus*	100			
Pre-control	European Rabbit	*Oryctolagus cuniculus*	5			
Pre-control	Sugar Glider	*Petaurus breviceps*	95	5		
Pre-control	Common Ringtail Possum	*Pseudocheirus peregrinus*	95			5
Pre-control	Greater Glider	*Petauroides volans*	100			
Pre-control	Sugar Glider	*Petaurus breviceps*	80	5		15
Pre-control	Swamp Rat	*Rattus lutreolus*	100			
Pre-control	Swamp Rat	*Rattus lutreolus*	100			
Pre-control	Swamp Rat	*Rattus lutreolus*	80			
Pre-control	Swamp Rat	*Rattus lutreolus*	95			
Pre-control	Mountain Brushtail Possum	*Trichosurus cunninghami*	100			
Pre-control	Mountain Brushtail Possum	*Trichosurus cunninghami*	90		10	
Pre-control	Mountain Brushtail Possum	*Trichosurus cunninghami*	80		20	
Pre-control	Mountain Brushtail Possum	*Trichosurus cunninghami*	80	10	10	
Pre-control	Mountain Brushtail Possum	*Trichosurus cunninghami*	100			
Pre-control	Mountain Brushtail Possum	*Trichosurus cunninghami*	80	20		
Pre-control	Mountain Brushtail Possum	*Trichosurus cunninghami*	10			
Pre-control	Mountain Brushtail Possum	*Trichosurus cunninghami*	60	30	10	
Pre-control	Mountain Brushtail Possum	*Trichosurus cunninghami*	95			5
Pre-control	Mountain Brushtail Possum	*Trichosurus cunninghami*	100			
Pre-control	Mountain Brushtail Possum	*Trichosurus cunninghami*	100			
Pre-control	Mountain Brushtail Possum	*Trichosurus cunninghami*	90			10
Pre-control	Mountain Brushtail Possum	*Trichosurus cunninghami*	100			
Pre-control	Mountain Brushtail Possum	*Trichosurus cunninghami*	100			
Pre-control	Black Wallaby	*Wallabia bicolor*	90		10	
Pre-control	Black Wallaby	*Wallabia bicolor*	20		40	40
Pre-control	Black Wallaby	*Wallabia bicolor*	100			
Pre-control	Black Wallaby	*Wallabia bicolor*	100			
Pre-control	Black Wallaby	*Wallabia bicolor*	100			
Pre-control	Black Wallaby	*Wallabia bicolor*	100			

Appendix 3 Guidelines for establishing and maintaining Red Fox control bait stations

Readers should refer to current legal and business requirements applying to the establishment and maintenance of bait stations within their jurisdiction.

The following guidelines are intended to assist with the establishment and maintenance of bait stations but do not replace the above:

1. Select sites within the designated area (see attached maps) where foxes are likely to be active and along thoroughfares likely to be used by foxes. Avoid locating bait stations in areas of high public use.
2. Check supplied land tenure maps to be certain that the bait station is located on public land and not private freehold.
3. Bait stations must be <u>no closer than 500m apart</u> to avoid bait caching. Bait stations should preferably be spaced at approximately 1 kilometre intervals.
4. Baits must be buried according to the label at a depth of 10 cm or more. A stick coated with fish oil can be used to help attract foxes to the bait station.
5. An area of 70 x 70 cm should be dug over or raked around the buried bait and soil of a consistency that allows animal prints to be detected.
6. Each bait station should be numbered with numbers marked on cattle ear tags tied to trees above bait stations. NB: Ensure no nails are used to fix marker tags to avoid spreading Myrtle Wilt.
7. Each bait station should be recorded as a GPS waypoint or the coordinates recorded and given to the PV project manager so that their locations can be mapped.
8. Ensure all neighbours have been notified before commencing baiting. Parks Victoria will notify neighbours prior to commencement of each baiting pulse.
9. Place 1080 poison baiting signs at all vehicle entry points and other commonly used entry points immediately before baits are laid.
10. Commence six week or appropriate pulse of poison baiting. A stick coated with fish oil can be used to help attract foxes to the bait station.
11. Check bait stations during poison baiting period weekly and accurately record the following information:
    - Bait station number and grid reference
    - Is the current bait a free-feed or poison bait?
    - Date and time
    - Current weather conditions
    - Has the bait been taken?
    - Is there evidence of animal tracks or scats at the bait station? What species are they from?
    - Was the bait replaced? Was it replaced with a free feed or poison bait?
12. Replace baits that have been taken and if baits are not taken for a two week period replace them with a fresh bait.
13. At the completion of the baiting period remove all untaken baits and dispose of them in accordance with the ‘Directions for the Use of 1080 Pest Animal Bait Products’.

January 11 2011
Media Contact:

Department of Sustainability and Environment

Media Release

Native species return as predators outfoxed in Stanley State Forest

A predator control program in bushfire affected Stanley State Forest, near Beechworth, is aiding the survival of endangered native animals by reducing fox numbers.

The program, which is set to continue into its second year, is targeting foxes.

DSE Pest Plant and Animal Management Officer, Jack Harrington, said funding to continue the control works will directly benefit native animals.

"The Beechworth area is home to numerous threatened species, including the Brush-tailed Phascogale and Spot-tailed Quoll," Mr Harrington said.

"The disruption to their habitat by bushfire presents a significant challenge to their survival; and the threat of pest animals makes it even harder."

The Beechworth-Library Rd fire burnt through 31,000 hectares of land in February 2009, including most of Stanley State Forest.

Mr Harrington said initial evaluation of the program found that the first round of baiting had been a success.

"We've had a good number of baits taken and importantly, we're hearing from local landholders reports of native animals which haven't been present in the area for some years."

Research has shown that effective predator control requires multiple rounds of baiting if fox numbers are to be reduced.

"The first baits were laid in this area in December 2009," Mr Harrington said.

"We then continued baiting in 2010, and we will resume with another round this year," Mr Harrington said.

"By taking this intensive approach to the program, we maximise the protection of threatened species."

Foxes and wild dogs are declared pest animals under the *Catchment and Land Protection (CaLP) Act 1994.* Areas treated with baits will clearly display 1080-baiting notices.

The predator control program is jointly funded by the Federal Government's Care for our Country program and the Victorian Bushfire Reconstruction and Recovery Authority.

For more information on bushfire recovery visit www.dse.vic.gov.au or call the DSE Customer Service Centre on 136 186.

www.depi.vic.gov.au