Summary and Overview of

Control and Ecology of the Red Fox in Western Australia - Prey Response to 1080 Baiting Over Large Areas.

Operation Foxglove

for the period
1 July 1997 to 30 June 1999

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Research Staff: 1 July 1997 – 30 June 1999

Position	Person	Period engaged	Percentage of time allocated	Funding Source
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Contract Technical Officers/Consultants:	Kathryn Himbeck	1 July 1997- 30 June 1998 1 July 1998 – 13 Nov. 1998 11 Jan. 1999 – 26 Feb. 1999 24 March 1999 – 18 May 1999	100	VB CRC
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	Beth MacArthur	1 July 1997- 30 June 1998 1 July 1998 – 13 Nov. 1998 11 Jan. 1999 – 26 Feb. 1999 24 March 1999 – 18 May 1999	100	VB CRC
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Volunteers (hours):

Mara Apgar (108), Kate Bryant (44), Kathryn Clarkson (38), Bradley Cox (44), Lisa de Groot (128), Robyn du Bois (52), Kate Johnson (147), Nick Jones (133), Sarah Kivell (49), Craig Lipnicki (38), Emma Pinnick (142), Kevin Pollard (78), Margaret Robertson (20), Suzanne Rosier (634), Rita Tan (267), Chris Trethowan (218), Linda Trunkfield (30), Sandy Turton (95).

Total volunteer hours 2264

CALM: Western Australian Department of Conservation and Land Management
EA: Environment Australia
VB CRC: Vertebrate Biocontrol Cooperative Research Centre

1. Background

Although disputed in the scientific literature, numerous studies in Western Australia have shown that fox control, using 1080 dried meat baits (fresh meat injected with 4.5mg sodium monofluoroacetate, then dried to approximately 60% of the fresh weight), results in increases in native fauna abundance.

Species believed to have benefited as a result of fox control include the rock wallaby, *Petrogale lateralis*, (Kinnear *et al.* 1988), the numbat, *Myrmecobius fasciatus*, (Friend 1990), the woylie or brush-tailed bettong, *Bettongia penicillata*, (Christensen 1980; Kinnear unpublished and personal communication), the chuditch, *Dasyurus geoffroii*, (Morris unpublished and personal communication), the common brushtail possum, *Trichosurus vulpecula*, and more recently the western ringtail possum, *Pseudocheirus occidentalis*, (de Tores, Rosier and Paine unpublished).

The fox control programs implemented to achieve these results have been at high baiting intensities and/or high baiting frequencies, and in most cases, within relatively small reserves.

Unpublished research in Western Australia demonstrated that 1080 baiting at an intensity of 5 baits/km^2 resulted in an 80% or greater uptake of 1080 meat baits by foxes (P. Thomson and D. Algar unpublished and personal communication). On the basis of this research, 5 baits/km^2 has been adopted as the standard baiting intensity for aerial delivery of 1080 dried meat baits in conservation estate and multiple use forest in Western Australia. However, the most efficient and cost effective baiting frequency is unknown. It is generally presumed that small areas, with a large perimeter to area ratio, require baiting as frequently as every 4 weeks. Implementing baiting regimes at this frequency over large areas is cost prohibitive for state agencies responsible for conservation of native fauna. Unpublished research suggests 4 baitings per year may be sufficient for effective fox control over large areas. However, there are no data to show that the entire suite of mammal fauna will increase in abundance at 4 baitings per year and anecdotal accounts suggest that increases do not occur at the perimeter of baited areas or at forest/agricultural land margins.

2. Objectives

Operation Foxglove is the largest fox control and research program undertaken within Australia and has compatible research and management objectives. Operation Foxglove was the precursor to CALM's broad scale 1080 baiting initiative Western Shield and is providing essential information for large scale operational baiting programs.

The specific research objectives of Operation Foxglove are:

1. to enable the suite of native mammal fauna to increase in abundance within the northern jarrah forest of south west Western Australia;
2. to determine cost effective baiting regimes that will result in increases in native fauna abundance over large areas – this has immediate operational value to broad scale baiting programs, including CALM's Western Shield fauna recovery program;
3. to assess the level of fox density reduction required to result in a sustainable increase in native fauna abundance;
4. to determine whether fox predation is the major limiting factor to native fauna abundance within the northern jarrah forest;
5. to determine whether translocated populations of the indicator species (woylie) have established viable populations;
6. to reduce fox density sufficiently to enable other threatened species to be translocated to fox baited areas within the northern jarrah forest. Translocations have been carried out as part of other projects and include translocations of the western ringtail possum to sites within the Lane Poole Reserve (the largest conservation reserve within the northern jarrah forest and within the 6 baitings per year treatment), translocations of the noisy scrub bird (also to Lane Poole Reserve) and translocations of the numbat to Dale Forest Block; and

7. to raise community awareness of the benefits that can be achieved through effective *in situ* fox control (cf. fenced enclosures).

The project is an integral part of the Pest Animal Control Cooperative Research Centre (PAC CRC) (formerly the Vertebrate Biocontrol CRC). The PAC CRC is developing fertility control agents as a means of controlling vertebrate pest species. The northern jarrah forest research is part of the research being undertaken to develop fertility control of the red fox.

The specific goal of the PAC CRC fox research in the northern jarrah forest is to determine the level of fox density reduction required to allow native fauna populations to increase and be sustained. This required level of fox density reduction will set the target for the level of fox density reduction required by fertility control or by a combination of lethal control measures and fertility control.

3. Study Area, Design and Techniques

3.1. The study area

The study area is approximately 544,000ha of jarrah/marri/wandoo forest within the northern jarrah forest of southwest Western Australia and is shown in figure 1.

The study area has three baited treatments and an unbaited control. Treatments, and areas covered by each treatment respectively, are:

- 2 baitings per year: 221,400ha.
- 4 baitings per year: 130,400ha.
- 6 baitings per year: 88,600ha.
- Unbaited control: 103,500ha.

Treatment boundaries are shown in figure 2 (in sleeve inside back cover).

3.2. Experimental design and techniques

3.2.1. General

Anecdotal accounts and results from *ad hoc* fauna trapping indicated that, prior to commencing the project, native fauna populations from the northern jarrah forest were at low density. In other fox control programs in Western Australia, a 4-5 year period post commencement of 1080 baiting was required before an increase in abundance was detected through trapping. As a result of the low native fauna abundance in the northern jarrah forest, it could be expected to take in excess of 5 years post commencement of fox control for conventional trapping techniques to detect a fauna response.

To detect a response within a shorter time frame, populations of the woylie, *Bettongia penicillata*, were translocated to the study area and intensively monitored through the use of radio-telemetry. The woylie was selected for translocation and considered a suitable indicator species for the ground dwelling mammals susceptible to fox predation as:

- it has been shown to respond to reductions in fox density (Kinnear unpublished and personal communication), females reach sexual maturity at 6 months and can produce up to 3 young per year; and
- it has been successfully translocated from Dryandra Woodland to Boyagin Nature Reserve (both are wheatbelt reserves within 45km of the eastern margin of northern jarrah forest study area) (Kinnear unpublished and personal communication), it was locally extinct from the northern jarrah forest and its former geographic range included the northern jarrah forest study area (Christensen 1980; Christensen 1995).

3.2.2. Woylie translocation protocols

All translocated woylies were sourced from Dryandra Woodland.

Standard "Sheffield" wire cage traps were set on roadside transects. The condition of each captured woylie was assessed. Standard morphometrics were recorded. Pouch condition was recorded for all females and size, weight and sex of pouch young was recorded.

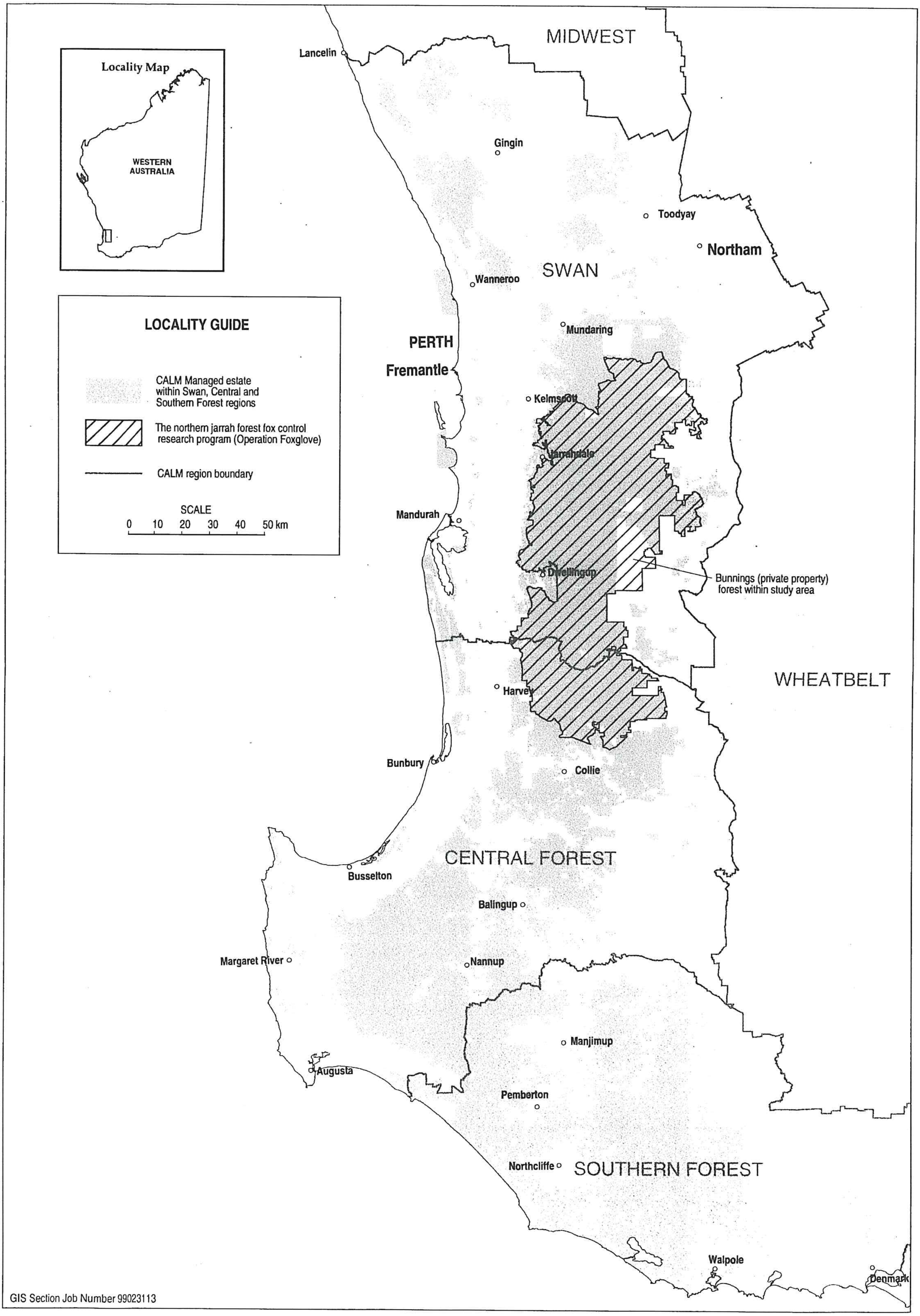


Figure 1. Location of the northern jarrah forest fox control and reserach program - Operation Foxglove

All translocated woylies were sedated (de Tores *et al.* in prep) prior to processing to minimise stress associated with capture and handling. Only woylies above a weight of 800g were translocated.

Every translocated woylie was implanted with an inert transponder (Trovan®) to provide an unambiguous identification.

Ear tissue samples were collected from a subset of the translocated stock and samples stored for subsequent analysis.

A female:male ratio of 3:2 was used for the initial pilot translocation. The same ratio was used for the first release at each of the remaining release sites.

Supplementary translocations were at ratios required to maintain 1:1 ratio of the radio-collared sample.

32 woylies were radio collared as part of the pilot translocation and a 368 of the 492 translocated woylies were radio-collared.

All releases were at night and within 18 hours of initial capture.

Radio-collar configuration incorporated 2 stage transmitters, with movement sensitive mortality circuitry and a 2½ hour period required to trigger mortality mode. Collars were fitted with a whip aerial and configured to minimise weight, maximise cell life and maximise signal strength (i.e. configured to maximise pulse length without compromising cell life). Alignment of cell and tag and positioning of whip emergence from the collar was designed to minimise injury to woylies. Radio-telemetry survivorship monitoring was undertaken daily for the pilot translocation and for 24 days of each 28 day period for subsequent translocations.

3.2.3. Monitoring protocols

The survivorship of translocated woylies and changes in abundance of the suite of small to medium size native fauna is monitored in each treatment through:

- twice yearly trapping over 4 consecutive nights at initially 43, and subsequently 55, trapping grids. Each grid is approximately 10ha. and is comprised of 25 wire cage "Sheffield" traps, 15 Elliott traps and 15 pitfall traps. The additional 12 grids were established prior to the Winter 1998 trapping session. These grids were added to enable trapping in unlogged and long unburnt forest types. From the Winter 1998 trapping session, trapping frequency was increased from 2 to 4 sessions per year. The trapping grid locations are shown in figure 2;
- twice yearly trapping over 4 consecutive nights at 17 transects, each 5km long. From the Winter 1998 trapping session, the frequency of transect trapping was also increased from 2 to 4 sessions per year. Transect locations are shown in figure 2;
- intensive radio-telemetry monitoring of translocated woylies; and
- radio telemetry monitoring of resident common brushtail possums.

All trapping grid and transect locations are within a 500ha. nominal buffer zone. The buffer zones have no planned burns prior to 30 June 2000 and are excluded from timber harvesting for the period to 30 June 2000. Buffer zone boundaries were determined during the project's site selection process and in conjunction with CALM's fire protection branch (CALM*fire*), CALM's Forest Management Branch and Alcoa's mining plan. Boundaries are digitised, mapped and incorporated into CALM's District operational plans to minimise conflict between operational and research requirements.

Similarly, the location of each of the 25km^2 areas used for deriving an index to fox density (see below) is mapped on district operational plans.

An index to fox density is derived annually (September–October) through the use of sandplotting. Each sandplot is approximately 1m x 1m. Neighbouring sandplots are set at a minimum spacing of 500m. Each sandplots is set at or near the roadside using the existing road and track network. Each group of 25 sandplots is termed a sandplot grid. There are 4 sandplot grids set in each of the 4 and 6 baitings per year treatment and the unbaited control, and 5 in the larger, 2 baitings per year treatment. Each grid covers an area of $25km^2$.

A non-toxic lure (~50g cube of fresh mutton) is placed 1-2cm below the sand surface, the surface is raked smooth and sprayed with a mist of water. Sandplots are examined daily for 10 consecutive days. Taken lures are replaced and sandplots raked smooth and re-watered.

Radio-telemetry monitoring of foxes was proposed to determine:

- whether foxes were surviving successive 1080 baiting events;
- the home range size of foxes within the northern jarrah forest; and
- whether foxes were moving between treatments and between forest and agricultural land.

Monitoring of fox survivorship, home range and movement was proposed through the use of satellite telemetry and/or movement sensitive mortality radio-telemetry.

3.2.4. Data analysis

Survivorship of radio-collared woylies and common brushtail possums

Kaplan-Meier survivorship functions modified for staggered entry and the non-parametric Log-Rank test (Pollock *et al.* 1989a; Pollock *et al.* 1989b) are used to analyse survivorship of woylies and common brushtail possums. The more conservative form of the Log-Rank test is used (with modified variance for number of deaths) (Pollock *et al.* 1989a). If appropriate, final analysis will incorporate an adjustment for censored animals (lost radio signals) to eliminate bias in the survivorship estimate (Bunck *et al.* 1995).

Fauna trapping

Analysis of final trapping data is proposed through use of the "Robust Model" used to derive density estimates from sampling closed and open populations (Pollock 1982; Pollock *et al.* 1990; Kendall and Pollock 1992; Kendall *et al.* undated) and/or the recently developed MARK software (G. White, Department of Fishery and Wildlife Biology, Colorado State University, USA). Use of these techniques will be subject to meeting assumptions of the models. Density estimates will be analysed in conjunction with a range of site specific habitat variables (including burning and logging history) and the level of fox density reduction imposed for the treatment.

Home range analysis

Home range is determined for the common brushtail possum, using the Harmonic Mean Measure (HMM) with 95% isopleths (Dixon and Chapman 1980) and RangesV software (Kenward and Hodder undated). Locations (fixes) used for home range analyses are obtained with a Global Positioning System (GPS). All fixes obtained prior to July 1999 were determined from an average of 10 readings (individual fixes) and only those averages with a standard deviation of 4.0 or less and a Position Dilution of Precision (PDOP) of 6.0 or less were accepted for use in home range analyses. Fixes obtained from July 1999 are determined by differential GPS.

Satellite telemetry may be used to determine survivorship and home range for foxes within the study area. Funding is currently unavailable for this component of the study.

Index to fox density

Fox activity at each plot is determined by the presence/absence of spoor. Caughley (1977) proposed that the frequency of occurrence at a monitoring point (in this case, a sandplot) was a function of population density of the monitored species. The underlying assumption is that activity or interference at each sandplot is independent. This assumption is violated in the case of sandplots used to derive an index to fox density, as foxes exhibit a learned behaviour. A variation of the Caughley model has been adopted, whereby a series of consecutive sandplots showing interference is interpreted as a single fox. A break in continuity of two or more consecutive sandplots, followed by subsequent sandplot(s) showing interference is interpreted as a second fox.

A cumulative mean is calculated at the completion of 10 days monitoring.

The procedure is yet to be validated.

Data storage

All trapping and radio telemetry data were stored on a relational database (MS Access) conforming to database normalisation protocols (Yung *et al.* in prep).

4. Progress in major activities

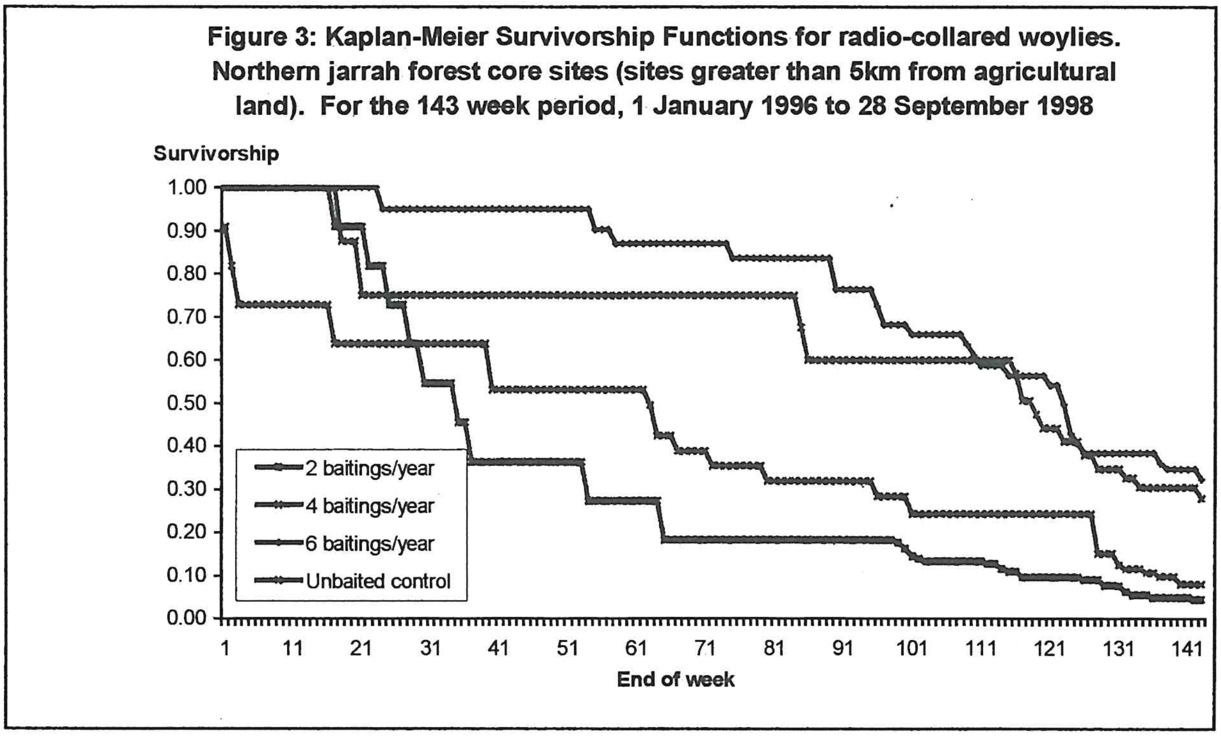
4.1. Woylie survivorship

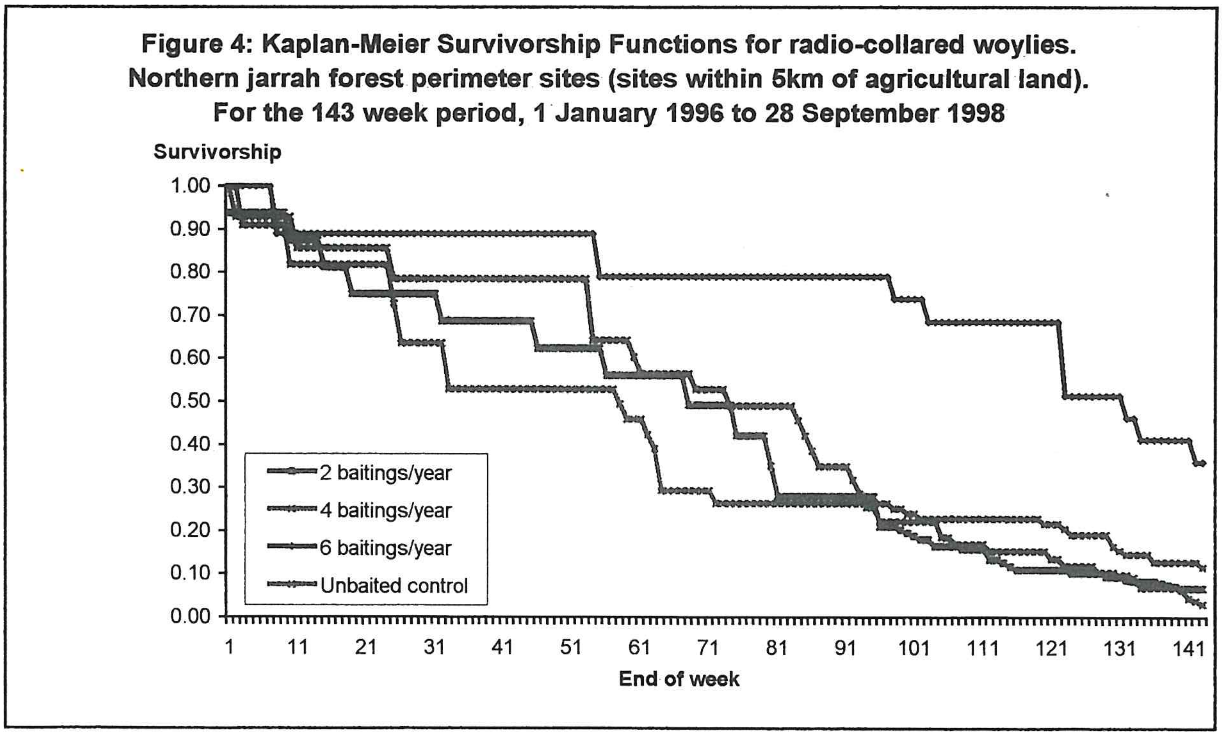
A total of 492 woylies was translocated in the period 25 January 1995 to 3 July 1998. Table 1 shows the numbers translocated and radio-collared at each treatment. In most cases radio collaring was at the time of translocation, however some translocated woylies, initially released un-collared, were subsequently radio collared to maintain the sample size of the monitored population. Similarly, a subset of recruits to the population was radio collared to maintain the sample size.

Table 1: Number of woylies, *Bettongia penicillata*, translocated to each treatment within the northern jarrah forest between the period 25 January 1995 and 3 July 1998.

Treatment	Number of translocated woylies	Number of radio collared woylies
2 baitings per year	154	127
4 baitings per year	132	86
6 baitings per year	122	85
Unbaited control	84	70
Total	492	368

The woylie radio telemetry study concluded at 30 September 1998. Results showed significant differences in survivorship between treatments and indicated that 4 baitings per year resulted in sufficient fox density reduction in core areas and 6 baitings per year was required to achieve sufficient reduction in fox density at forest margins (figures 3 and 4).





Implications for baiting regimes

The woylie was selected as an indicator species for the northern jarrah forest study as it is considered to be indicative of species sensitive to fox predation and is known to respond to fox density reduction. The results indicate that woylie populations at the perimeter of forest areas are more susceptible to predation than populations in central core areas of forest.

The assertion is supported by anecdotal evidence and unpublished data from three Western Australian locations (Tutanning Nature Reserve, Dryandra Woodland and Perup Forest) where the woylie was known to have persisted, where baiting regimes are now in place and where *ad hoc* trapping indicates reduced abundance at reserve boundaries.

If the northern jarrah forest survivorship results for the woylie are indicative of the response of the suite of mammal fauna in the northern jarrah forest and elsewhere, aerial baiting regimes for fox control using 4.5mg 1080 dried meat baits should include the following as part of the prescription:

- a baiting intensity of 5 baits/km^2;
- a baiting frequency of 6 times per year to provide a 5km wide buffer between forest/conservation estate and agricultural land or other unbaited areas; and
- a baiting frequency of 4 times per year to areas greater than 5km from agricultural land.

The above regime is not consistent with current broad-scale aerial baiting prescriptions in Western Australia, where, in most cases, large areas are baited at a frequency of either 2 or 4 times per year. The regime proposed above will necessitate some additional costs as a result of the increased baiting frequency at perimeter sites. Baiting perimeter areas may also necessitate vehicle delivery of baits to forest margins where accuracy of aerial delivery cannot be guaranteed.

Alternative regimes, proposing strategic baiting at a frequency less than 6 times per year, have been independently proposed (Saunders *et al.* 1995) and proposed in response to presentations of the northern jarrah forest research findings. The rationale for less frequent, strategic baiting is based on the premise that fox predation is seasonal, with peaks in the frequency of predation events at identifiable periods, such as January to mid March when young are dispersing and in July, during mating season, when home range barriers are thought to have broken down.

There is no evidence from the northern jarrah forest research to support the hypothesis of differential seasonal predation, however peaks in woylie predation are associated with translocation releases. Similarly, evidence from the 1998 estimate of fox density derived from sandplotting and recent incidental sightings indicated fox presence within the central core of the 6 baitings per year treatment within 2 months of the July 1998 aerial baiting and within one month of the July 1999 aerial baiting. Implicit in this, and from the lack of evidence of seasonal peaks in predation events, is that fox dispersal into baited areas occurs year round (see section 4.4).

The above baiting regime is recommended on the basis of the woylie radio telemetry study alone. The woylie survivorship data are not supported by common brushtail possum radio telemetry data nor trapping data. **It is therefore recommended that the current northern jarrah forest baiting regimes are maintained until data from longer term trapping are analysed** (see following sections).

If, and when, an amended baiting regime is implemented, feral cat abundance should be closely monitored (see section 4.3).

4.2 Survivorship of the common brushtail possum

Results from radio telemetry monitoring of survivorship of radio collared common brushtail possums showed no detectable difference between treatments. The lack of a detectable difference in survivorship indicated that fox predation was not limiting common brushtail possum abundance. However, lack of a detectable difference in survivorship may also be attributable to the small sample size and the absence of juvenile and sub-adult possums in the monitored sample.

A breakaway collar, suitable for use on juvenile and sub adult animals, is currently being developed.

Insecurity of funding, and the resultant stop/start nature of the research has necessitated curtailing of survivorship monitoring of the common brushtail possum. Radio collars have been removed from all possums in the 2 and 4 baitings per year treatment. Any further radio telemetry monitoring of common brushtail possums is subject to continued funding and will be restricted to the 6 baitings per year treatment and the unbaited control.

4.3. Trapping to assess the native fauna response to different levels of fox density reduction

Selection of fauna trapping grids and preliminary (pre baiting) fauna survey commenced in July 1993. Twice yearly trapping (Summer and Winter) commenced in Summer 1994-95. Additional CALM funding was provided in 1997-98 to establish additional trapping grids. The grids were established in Autumn 1998 to enable sampling in long unburnt habitat and unlogged forest.

From Winter 1998 trapping frequency was increased from 2 to 4 trapping sessions per year, in accordance with the operational plan schedule. The frequency of trapping was increased to allow appropriate analysis of trapping data (Mark-Recapture analysis using the Robust Model, see section 3.2.4.).

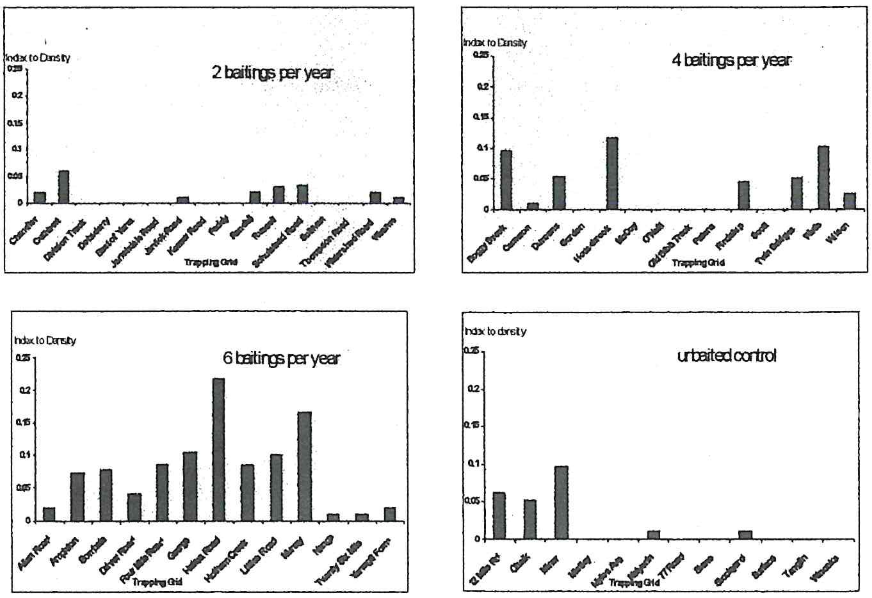
To determine whether fox predation is a major limiting factor to native fauna abundance within the northern jarrah forest, final density estimates will be analysed in conjunction with a range of site specific habitat variables (including burning and logging history) and the level of fox density reduction imposed for the treatment.

Interim results from trapping (figures 5-7) show the derived index to density for *Dasyurus geoffroii*, *Trichosurus vulpecula* and *Isoodon obesulus* for the 1998-99 Summer trapping session. Data are shown for each trapping grid in each treatment. The results are shown as percentage capture success transformed to give an index to density. Data were transformed because of the non linear relationship between capture rate and density at capture frequencies above 0.2 (Caughley 1977).

The data show no consistent relationship between density and frequency of baiting.

Some caution must be exercised when interpreting the interim results from the trapping data. With the exception of *Dasyurus geoffroii* in the 6 baitings per year treatment, the results to date indicate no apparent response to fox control.

Figure 5: Index to density, *Dasyurus geoffroii*



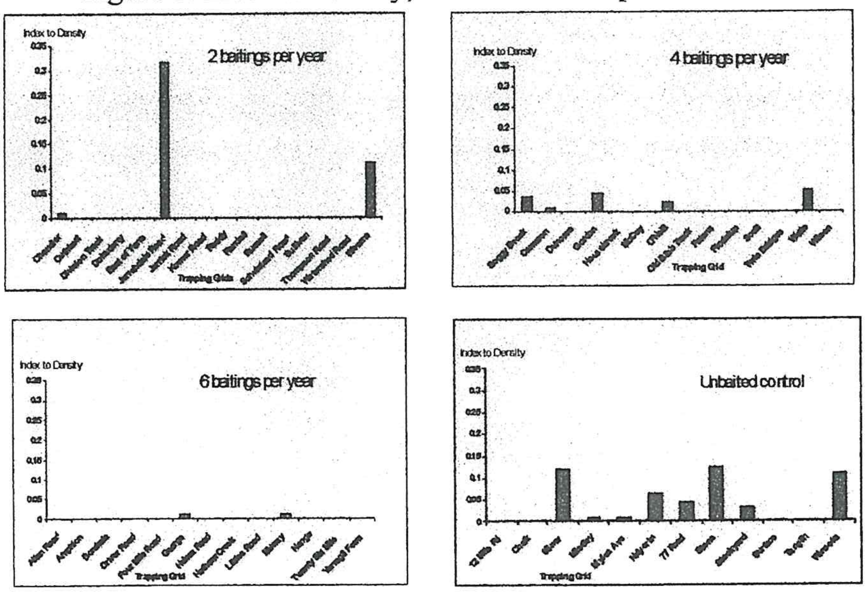
The simplest, and intuitive, explanation for a lack of a detectable response, is that there has been insufficient time since the commencement of fox control for prey numbers to increase.

The experimental design acknowledged a 5 to 7 year period would be required for a response to be detected through conventional trapping techniques. January 2000 marks 5 years since commencement of baiting in the 6 baitings per year treatment. Given the extremely low native fauna density pre fox control, the 5 to 7 year time frame may be an underestimate.

Premature analysis of the data may lead to acceptance of the null hypothesis, i.e. that there is no difference in fauna abundance between treatments. This may result in a Type 2 error. The consequences of a Type 2 error may be a false interpretation that habitat variables alone, and not fox predation, are limiting native fauna abundance. Managers would be given the message that there is no conservation benefit from fox control. This conflicts with the results from the woylie translocation and monitoring study and is counter intuitive to the Western Australian experience with fox control.

The skewed nature of fauna abundance is demonstrated by trapping data for *Trichosurus vulpecula* (figure 6). *Trichosurus vulpecula* trapping data show the highest densities at some long unburnt grids (e.g. the 62 year unburnt Jarrahdale Road Grid, within the 2 baitings per year treatment), unlogged sites (e.g. Miner Grid within the unbaited control) and sites dominated by *Eucalyptus wandoo* (e.g. Wearne Grid within the 2 baitings per year treatment and Stene and Winooka Grids from the unbaited control).

Figure 6: Index to density, *Trichosurus vulpecula*

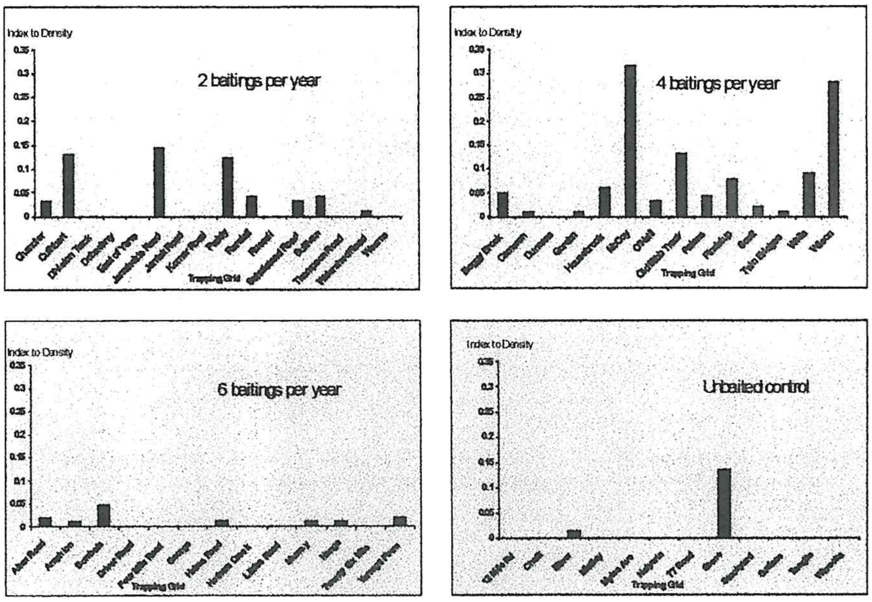


The implication is that abundance and distribution of *T. vulpecula* within the northern jarrah forest may be determined by habitat factors including logging and burning history. A feasible alternative interpretation is that these factors determine *T. vulpecula* abundance and distribution in the northern jarrah forest, but only in the absence of predator control or in the absence of adequate control.

Similar conclusions can be drawn from the data on density of *Isoodon obesulus* (figure 7). Clearly it is essential to allow sufficient time post commencement of fox control, to enable a response to be detected.

The lack of a detectable response may also be a function of compensatory mortality, i.e. increased predation by cats may be compensating for a reduced level of fox predation. Increased abundance of feral cats has been associated with reductions in fox density at Heirisson Prong, Western Australia (D. Risbey, personal communication). There is some evidence to suggest this may also be the case in the northern jarrah forest. Similarly, increases in the abundance of the native predator, *Dasyurus geoffroii*, may also result in compensatory mortality and mask a fauna response. Clearly, the change in abundance of other predators needs to be taken into consideration when assessing the fauna response to a reduction in fox density.

Figure 7: Index to density, *Isoodon obesulus*

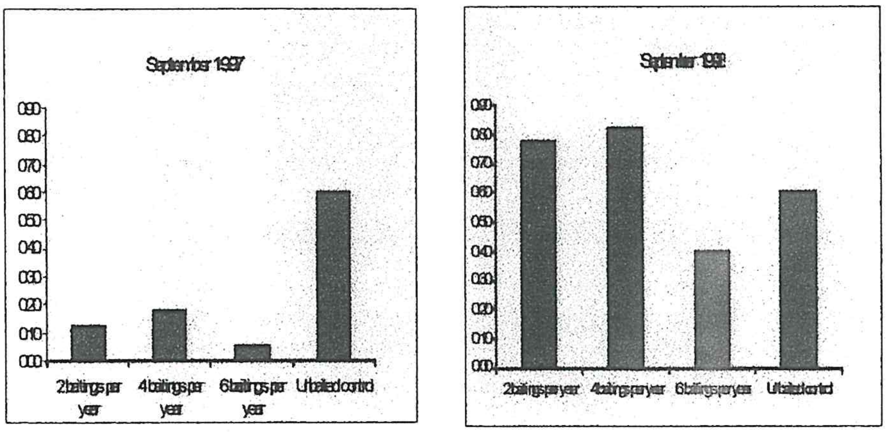


4.4 Fox density through the use of sandplots.

Estimates are derived in September/October when fox home range boundaries are considered most stable. Interpreting density estimates at this time of year is less likely to be confounded by the presence of dispersing young (January to March) or when home range boundaries break down during mating (June to July).

Fox density estimates derived from sandplotting in Spring 1997 and 1998 are shown in figure 8. The level of fox density reduction required to result in a sustained increase in native fauna abundance is still unclear. Derived estimates indicated fox density increased across all baited treatments between 1997 and 1998. Density in the unbaited treatment remained stable.

Figure 8: Derived index to fox density, northern jarrah forest, all treatments.
Shown as estimated number of foxes per 25km^2



The 1997 derived index to density in all baited treatments was less than the unbaited control. In 1998, although less than the unbaited control, the index to density from the 6 baitings per year treatment was higher than 1997, implying fox density had increased.

This may be seen as contrasting with the woylie survivorship data which indicated that fox density was reduced at core and perimeter sites in the 6 baitings per year treatment and at core areas in the 4 baitings per year treatment. The woylie survivorship data further implied this reduced density was maintained at a lower level than the 2 baitings per year and the unbaited control.

If it is accepted that fox numbers are reduced as a result of 1080 baiting, although it may be only temporarily, the elevated density in the 2 and 4 baitings per year treatment may be a reflection of immigration/dispersal from neighbouring agricultural land. The presence of foxes in the core area of the 6 baitings per year treatment was confirmed through trapping. Immediately after completion of the sandplot derived estimate of density, an adult male fox was trapped where sandplot evidence indicated fox presence. The fox was radio-collared and was subsequently confirmed to have taken a 1080 bait after the ensuing aerial delivery of baits to the 6 baitings per year treatment.

The inferences are that:

- immigration/dispersal may be continuous throughout the year;
- dispersing foxes are being "turned over" at a rate determined by the frequency of baiting; and
- in the unbaited control, population density is more stable, presumably as a result of resident individuals maintaining home range/territorial boundaries.

Although only weak inferences can be drawn, the results support the assertion that, in the presence of 1080 baiting, dispersal/recruitment into baited areas is not restricted to the traditionally perceived autumn juvenile dispersal and winter mating periods.

The technique used to derive the density estimate is yet to be validated.

5. Proposed schedule from July 1999

Subject to continued funding, the proposed schedule for the period to 31 March 2000 is:

- Seasonal trapping will be continued (Winter 1999, Spring 1999 and Summer 1999-2000) at each of the 55 integrated fauna trapping grids and each of the 17 trapping transects.
- An index to fox density will be derived through sandplotting within each treatment (September/October 1999, prior to the aerial baiting). An index to fox density will also be derived (October/November 1999) subsequent to the September/October aerial baiting. The indices to density will allow assessment of the level of fox density reduction achieved in each of the 3 baited treatments.
- The sandplotting technique will be validated (September/October 1999) through the use of cyanide baiting. The validation sites are Quindanning and Marradong forest blocks, immediately east of the study are (figure 2).
- Site specific habitat analysis will be undertaken at each of the 55 trapping grids (September to December 1999) to determine whether habitat variables and/or the level of fox density reduction achieved through 1080 baiting influence the abundance of native fauna (fauna abundance will be derived from trapping data).
- Analysis will also be undertaken to determine whether habitat variables and/or the level of fox density reduction achieved through 1080 baiting influence survivorship of radio collared woylies.

The project originally identified that a minimum period of 5-7 years would be required post commencement of baiting before a fauna response would be detected through trapping.

1080 baiting commenced in the 6 baitings per year treatment in January 1995. January 2000 is therefore anticipated as the earliest date that a response would be detected. Follow-up/longer-term monitoring is recommended beyond January 2000.

In the absence of a detectable response by June 2000, maintenance of the existing baiting regimes and longer term monitoring is recommended. The monitoring proposed is at a reduced intensity from the current northern jarrah forest protocols. A trapping program conducted over a 15 month period commencing Spring 2003 is recommended.

Funding for the 15 month monitoring period will be sought through corporate sponsorship.

A communication strategy, commencing March 2000, is proposed to incorporate the following:

- Annual trapping at 2-3 selected trapping grids as part of an education/eco-tourism package to demonstrate the benefits from *in situ* fox control. This is proposed to be self funding and/or supported through corporate sponsorship;
- Establishing/strengthening links with the Zoology Department of the University of Western Australia and, as part of the newly established Pest Animal Control CRC, incorporate selected sites and aspects of the northern jarrah forest study with the Pest Animal Control CRC education program; and
- Establishing, as part of CALM's web site, a site providing information on the northern jarrah forest fox control program.

Conclusion

There have been few experimental studies to test whether fox predation is limiting abundance of small to medium size mammal populations. There are two landmark Western Australian studies: the rock wallaby study (Kinnear *et al.* 1988; Kinnear *et al.* 1998) and the Western Australian numbat study (Friend 1990). Both studies have been criticised in the scientific and conservation management literature (see Hone 1994 and Caughley and Gunn 1996). Criticisms have concentrated on the scientific design and procedures. Specifically, the criticisms have identified weaknesses resulting from close proximity of treatments, lack of controls, lack of replication, lack of assessment of the importance of habitat variables and lack of confirmation of fox density reduction in areas where foxes were reported to be controlled.

Although probably not intended to do so, these criticisms have sent conflicting messages to conservation managers and agencies responsible for allocating conservation management funds. The result may be failure to implement effective conservation management practices.

One of the major objectives of the northern jarrah forest project was to undertake scientifically rigorous fox control and research, meeting the criteria accepted by the scientific community, to determine whether fox predation was a major limiting factor to native fauna abundance.

The northern jarrah forest research is the largest fox control and research program to be undertaken in Australia. It has implemented fox control at an appropriate scale to allow assessment of fauna response to fox density reduction over large areas. The experimental design has incorporated replicated fauna response monitoring sites (albeit pseudoreplication as necessitated by the large scale), pseudoreplicated control sites, effective habitat analysis, assessment of fox densities in all treatments, assessment of abundance of other predators and appropriate analysis of data.

To date the results from trapping are equivocal – primarily because the project has not run to its scheduled completion and some activities have been temporarily curtailed as a result of the insecurity of funding.

The project has been critically reviewed by international leaders in wildlife management and research including professors Tony Sinclair and Charles Krebs (University of British Columbia). At all stages of review the project has been praised for its scientific rigour and value to managers of conservation estate. The following is an extract from the most recent review by Professor A.R.E. Sinclair, Director, Centre for Biodiversity Research, University of British Columbia:

"Your Jarrah Forest experiment is the only one in the world that is examining what degree of predation that can be tolerated by endangered species. The results will allow us to predict what levels of predation and hence what densities of predators we have to reduce the predators to in order to preserve endangered prey species. One reason why your experiment is unique is that it is so difficult to do. You seem to have overcome the obstacles. In particular, there are two things that are in your favour. First, the scale of your experiment is right - it is operating on a realistic scale for the species and the ecosystem. Most predation experiments are trivially small scale and we cannot interpret the results. With yours we can. The second aspect of note is that you have expedited the results by using the release of the bettongs in each of your areas - this was an innovative procedure that has allowed you to get good results quickly. The results you presented at the annual meeting were very encouraging and I felt that you had the experiment working well. With time we should get the answers that we need. The bettong results were excellent. The other species were intriguing and I hope we can find out what is happening to them when we see all the data.

Despite these positive aspects we need to recognise that with mammals things take time and we need to have patience. We must not cut it short before we can get the important answers. At the very least you must continue your work according to the plan, that is until next March. Then we should have some lower level of monitoring that continues after that date to keep track of things, especially the prey populations.

I fully recommend that you continue the work until the scheduled term and that funding is provided. This is a great experiment and a credit to Australia. It is a flagship study that the rest of the world will look at."

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