FOX CONTROL 3.

1997-1998 Report to

ENVIRONMENT AUSTRALIA

NATIONAL FERAL ANIMAL CONTROL PROGRAM

ISF06638#
Control and Ecology of the Red Fox in Western Australia - Prey Response to 1080 Baiting Over Large Areas.

April 1999

(for the period 1 July 1997 – 31 March 1999)

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Summary

Increases in fauna abundance in several conservation reserves in Western Australia have been attributed to reductions in fox density achieved through the use of dried meat baits containing the poison "1080" (sodium monofluoroacetate). In most cases, the areas baited have been relatively small and the baiting regimes have incorporated high intensity and/or high frequency baiting.

Unpublished research in Western Australia has shown that baiting at an intensity of 5 baits/km^2 will result in an 80% or greater uptake of 1080 meat baits by foxes. However, the most efficient and cost effective baiting frequency is unknown. Baiting frequencies known to be effective over small areas are cost prohibitive if implemented over large areas.

The northern jarrah forest fox control and research project (***Operation Foxglove***) is designed to reduce fox density over large areas. The project's primary objective is to enable native fauna populations to increase and be sustained over large tracts of multiple use forest. The project is a major component of CALM's Western Shield 1080 baiting initiative.

The major research objectives are:

- to determine efficient and cost effective 1080 baiting regimes for fox control over large tracts of conservation estate and multiple use forest;
- to determine the level of fox density reduction required to allow native fauna populations to increase and be sustained; and
- to determine whether fox predation is a major limiting factor to native fauna abundance.

The study area covers approximately 544,000ha. and has 3 baited treatments and an unbaited control. 1080 dried meat baits are aerially delivered at 5 baits/km^2. Supplementary baiting, also at 5 baits/km^2, is carried out using conventional vehicle delivery in areas at the interface with agricultural land. Treatments and areas covered by each treatment are:

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

Fauna response to baiting is monitored in each baited treatment and the unbaited control. Fauna monitoring falls within four main areas:

- radio-telemetry monitoring of translocated populations of woylies, *Bettongia penicillata*;
- radio telemetry monitoring of resident populations of the common brushtail possum, *Trichosurus vulpecula*;
- conventional trapping of the suite of native fauna; and
- spotlight monitoring of the suite of native fauna.

Fox density is monitored in each treatment by deriving an annual index to density through the use of sandplots.

If successful in determining appropriate baiting regimes for large tracts of multiple use forest, the research will result in the establishment of populations of the woylie, *Bettongia penicillata*, throughout the northern jarrah forest.

In excess of 400 woylies have been translocated to the northern jarrah forest sites. Survivorship of translocated woylies has been intensively monitored through use of movement sensitive mortality radio-transmitters. Monitoring has shown significant differences in survivorship between treatments.

The results indicate that operational baiting regimes currently used by managers require modification to provide increased levels of fox control at the forest/agricultural land interface. If these results are confirmed by final analysis of data, changes to current aerial fox baiting regimes are recommended. Subject to final analysis, a revised aerial baiting prescription is specified.

Results from trapping are presented for the three most recent trapping sessions (Winter 1998, Spring 1998 and Summer 1998-99). These data are presented in the absence of site specific habitat analysis and, in lieu of more meaningful final analysis, are shown as percentage capture success transformed to give an index to density.

Trapping data do not support the radio-telemetry results and showed no significant difference in abundance between treatments for the three most frequently caught medium size mammals. Data are insufficient to determine whether fox predation alone is the major limiting factor to native fauna abundance. Trapping data are highly skewed and implicate site specific habitat variables as co-limiting native fauna abundance. Data collection is not complete and results should be interpreted cautiously.

Criticisms of published fox control research has questioned whether fox predation is a major limiting factor to native fauna abundance. These criticisms have sent conflicting messages to managers of conservation estate. These conflicting messages may result in failure to implement effective fox control.

The northern jarrah forest project sought 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.

To date the results are equivocal, primarily because the project has not run to its scheduled completion. The project is at a critical stage with less than 12 months field work remaining. It has achieved targeted outcomes, has been innovative and applied fauna translocation techniques and modern technologies. The technologies and analytical techniques have been appropriate for the specific tasks. It is the largest fox control and research program to be undertaken in Australia and has implemented fox control at an appropriate scale to allow assessment of fauna response to fox density reduction over large areas. The project has met the required criteria for scientific design.

Justification is presented for continued funding to the scheduled completion date.

The project commenced in 1993-94 as an approved Australian Nature Conservation Agency (ANCA) funded project. In 1996, a funding proposal was submitted to Environment Australia (EA). The proposal sought funding as a continuing project in accordance with the Commonwealth's Natural Heritage Trust (NHT) guidelines. The project was accepted as a continuing project and was scheduled for completion at 30 June 2000.

Although accepted as a continuing project with a completion date of June 2000, the project has a history of retrospective confirmation of NHT funding and insecurity of continued funding.

This history of funding has jeopardised support from co-funding agencies and corporate sponsorship. The delays in funding advice have also necessitated a stop-start approach to the research. This has compromised the research and jeopardised the project meeting identified outcomes and milestones.

NHT funding for the project for the 1996-97 financial year was retrospectively approved in November 1997. Funding for the 1997-98 financial year was approved in March 1998. There has been no formal advice of funding for 1998-99.

The 4 month period from 3 March to 30 June 1998, is the only period when NHT funding was secured prior to the need to incur expenditure.

In accordance with the application and approval as a NHT continuing project, the report for 1997-98 was to cover the period 1 July 1997 to 30 June 1998. Reports were also scheduled for June 1999 and June 2000. In view of the insecurity of funding, and the possibility of no further reporting requirement, this report covers the period from 1 July 1997 to 31 March 1999. This is well beyond the period for which NHT funds have been provided.

Report structure

This report is submitted to meet the requirements of the Agreement between the Commonwealth of Australia and the Western Australian Department of Conservation and Land Management for the funding period 1 July 1997 to 30 June 1998.

Progress reports have previously been submitted. The most recent was for the period 1 July 1996 to 30 June 1997.

Reports are also scheduled for June 1999 and June 2000. However, given the insecurity of continued funding for the project and the possibility of no further reporting requirements, this report covers the period 1 July 1997 to 31 March 1999.

The report provides a background to the research program, outlines the experimental design and methodology and provides results as at 31 March 1999.

Progress is reported to meet the requirements as outlined in Section D of the Agreement. Specifically, it summarises progress in the following major activities (as listed in Schedule 1 of the Agreement):

- Radio-telemetry monitoring of translocated populations of the woylie, *Bettongia penicillata*, and resident populations of the common brushtail possum, *Trichosurus vulpecula*.
- Twice yearly trapping at trapping grids and transects to assess the native fauna response to different levels of fox density reduction.
- Twice yearly spotlighting of 4 transects within each treatment to supplement trapping data.
- Derivation of an annual index to fox density through the use of sandplots.
- Trapping to supplement fox density estimates from sandplotting.
- Radio-telemetry monitoring of foxes.
- Collection of site specific habitat and management data.

Section 3, "History of Funding", outlines why certain of the above activities are not adequately addressed in the research to date.

Throughout the report, the project is assessed in terms of its appropriateness, effectiveness and transferability as per the requirements of Schedule 3 of the Agreement.

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

Research Staff: 1 July 1997 – 31 March 1999

Position	Person	Period engaged	Percentage of time allocated	Funding Source
Project Leader Research Scientist:	Paul de Tores	1 July 1997- 31 March 1999	100	CALM
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 – 31 March 1999	100	VBCRC
	Jim Cocking	1 July 1997- 30 June 1998 1 July 1998 - 13 Nov. 1998 11 Jan. 1999 – 26 Feb. 1999 24 March 1999 – 31 March 1999	100	EA CALM CALM CALM
	Beth MacArthur	1 July 1997- 30 June 1998 1 July 1998 – 13 Nov. 1998 11 Jan. 1999 – 26 Feb. 1999 24 March 1999 – 31 March 1999	100	VBCRC
	Marika Maxwell	7 July 1997- 30 June 1998 1 July 1998 - 13 Nov. 1998 11 Jan. 1999 - 26 Feb. 1999 24 March 1999 - 31 March 1999	100	EA CALM CALM CALM
	Nathan Millen	1 July 1997- 13 March 1998	100	EA
	Elizabeth White	1 October 1997- 13 March 1998	100	EA
	Wendy Van Luyn	1 July 1997- 14 July 1997	100	EA
	Michael Meffert	1 August 1997 - 31 August 1997	100	EA
Senior Technical Officer:	Mike Dillon	1 July 1997- 31 March 1999	75	CALM
Research Scientist:	Mike Yung	1 July 1997- 31 March 1999	1	CALM
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				

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).

Morris et al 1995

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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.

The northern jarrah forest fox control and research program (***Operation Foxglove***) commenced in 1993-94. The project was originally part of a larger research program funded by the Australian Nature Conservation Agency (ANCA). From 1996-97, the project has been funded by Environment Australia through the Natural Heritage Trust (NHT).

The project 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.

Operation Foxglove aims to reduce fox density sufficiently to result in increases in native fauna abundance over large areas of multiple use forest. The specific research objectives are:

- to determine efficient and cost effective 1080 baiting regimes for fox control over large tracts of conservation estate and multiple use forest; and
- to determine the level of fox density reduction required to allow native fauna populations to increase and be sustained.

In meeting these objectives, the project will determine whether fox predation is the major limiting factor to native fauna abundance in the northern jarrah forest.

The project is an integral part of the Vertebrate Biocontrol Co-operative Research Centre (VB CRC). The research undertaken comprises Project 3.4 within the VB CRC Ecology Program.

The specific goal of the VB 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.

In addition to the specific research objectives, the project will achieve fauna conservation management goals. The project will:

- Provide large areas of fox controlled forest habitat suitable for translocation of a range of threatened species considered locally extinct within the northern jarrah forest. These areas include large tracts of secure conservation estate such as Lane Poole Reserve where translocations of the western ringtail possum (*Pseudocheirus occidentalis*) and the noisy scrub bird (*Atrichornis clamosus*) have been carried out. Translocations of the numbat (*Myrmecobius fasciatus*) have also been carried out in other conservation reserves and state forest within the northern jarrah forest.
- Provide large areas of fox controlled forest habitat suitable for resident threatened species such as the chuditch (*Dasyurus geoffroii*) and quokka (*Setonix brachyurus*) to increase in abundance and range.

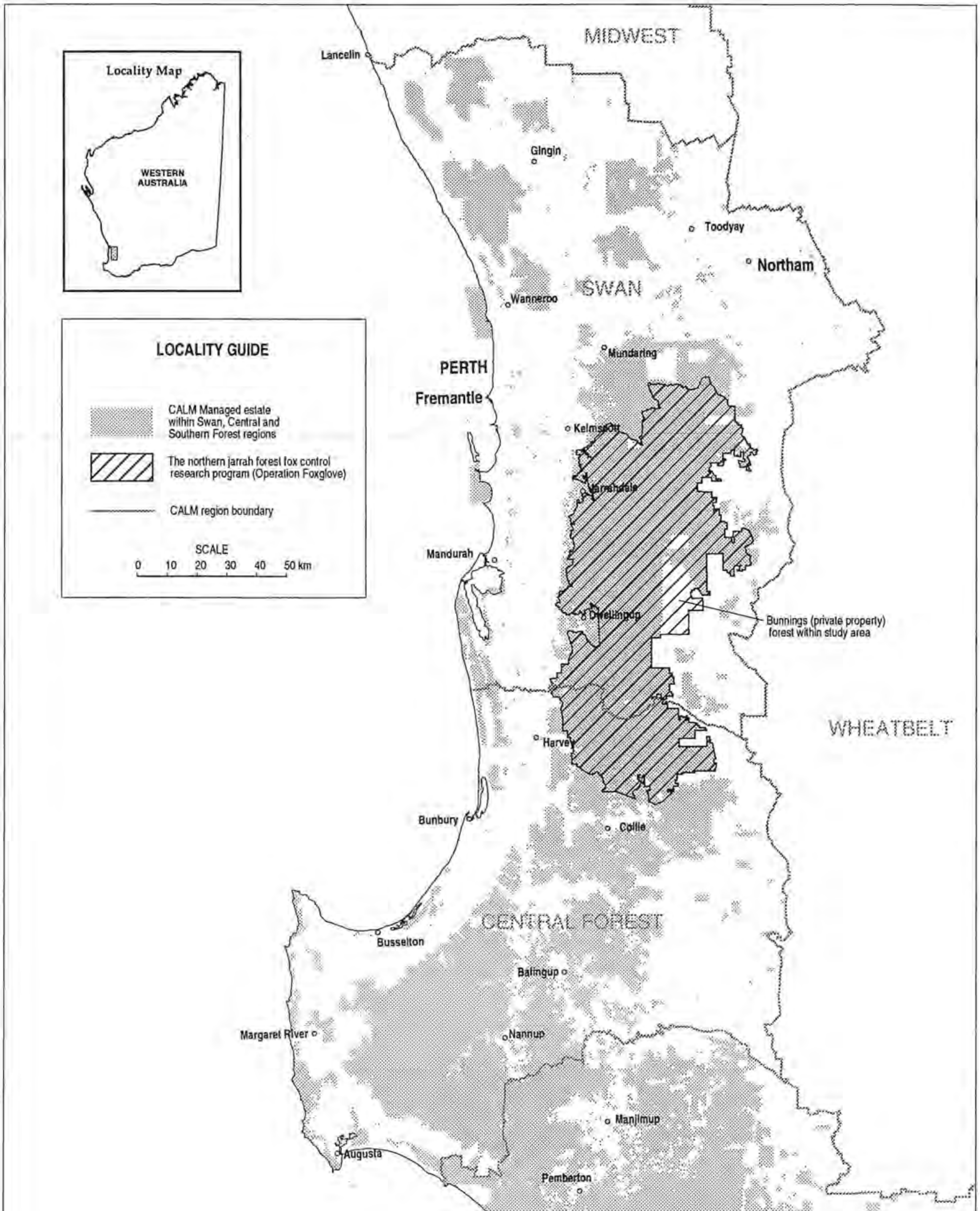

Figure 1. Location of the northern jarrah forest fox control and reserach program - Operation Foxglove

2. Study Area, Design and Techniques

2.1. 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).

2.2. Experimental design and techniques

2.2.1. General

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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 suite of northern jarrah forest 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).

2.2.2. Woylie translocation protocols

All translocated woylies were sourced from Dryandra Woodland, a wheatbelt conservation reserve 45km east of the northern jarrah forest study area.

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

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 ($DMSO_4$) 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.

2.2.3. 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. Prior to the Winter 1998 trapping session, the additional 12 grids were established 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. The trapping grid design is shown in figure 3;
- 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;
- twice yearly spotlighting over three consecutive nights at each of the 17 transects above;
- 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 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.

Subject to a proposed trial of satellite telemetry, monitoring of fox survivorship and movement was proposed through the use of satellite telemetry and/or movement sensitive mortality radio-telemetry.

2.2.4. 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). 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.

Interim results from trapping are shown as percentage capture success transformed to give an index to density (Caughley 1977).

Spotlighting

Spotlighting data will be analysed as per line transect model methodology and model selection as outlined by Buckland *et al.* (1993). In the absence of a sufficient number of sightings for meaningful analysis, data will be presented as number of sightings per linear transect per unit of time.

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 March 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 April 1999 are determined by differential GPS.

Subject to the outcome of the satellite telemetry trial, the HMM as above, is proposed for fox home range analysis. In the absence of suitable data from satellite telemetry, locations obtained from a light aircraft using single GPS determined fixes or differential GPS determined fixes will be used for diurnal locations. Subject to appropriate trials, nocturnal fixes will be determined by triangulation from hand held receivers from vehicles.

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).

3. History of funding

The northern jarrah forest project commenced in 1993-94 and was originally funded by the Australian Nature Conservation Agency (ANCA) as part of a larger project titled "Control and ecology of the red fox in Western Australia". This project included research other than that undertaken in the northern jarrah forest.

In 1996, a funding proposal was submitted to Environment Australia (EA). The proposal sought funding for the northern jarrah forest project as a continuing project in accordance with the Commonwealth's Natural Heritage Trust (NHT) guidelines. The project was accepted as a continuing project and was scheduled for completion at 30 June 2000.

Although accepted as a continuing project, confirmation of NHT funding has been unacceptably slow. Confirmation of NHT funding for 1996-97 was received verbally from EA in mid June 1997 (i.e. at the close of the financial year for which the funds were allocated) and formally on 3 November 1997. Confirmation of 1997-98 funding was also approved on 3 November 1997. However, this approval was subject to further negotiation. Verbal confirmation of 1997-98 funding was received on 3 March 1998.

Therefore, the 4 month period from 3 March to 30 June 1998, is the only period when funding was secured prior to the need to incur expenditure.

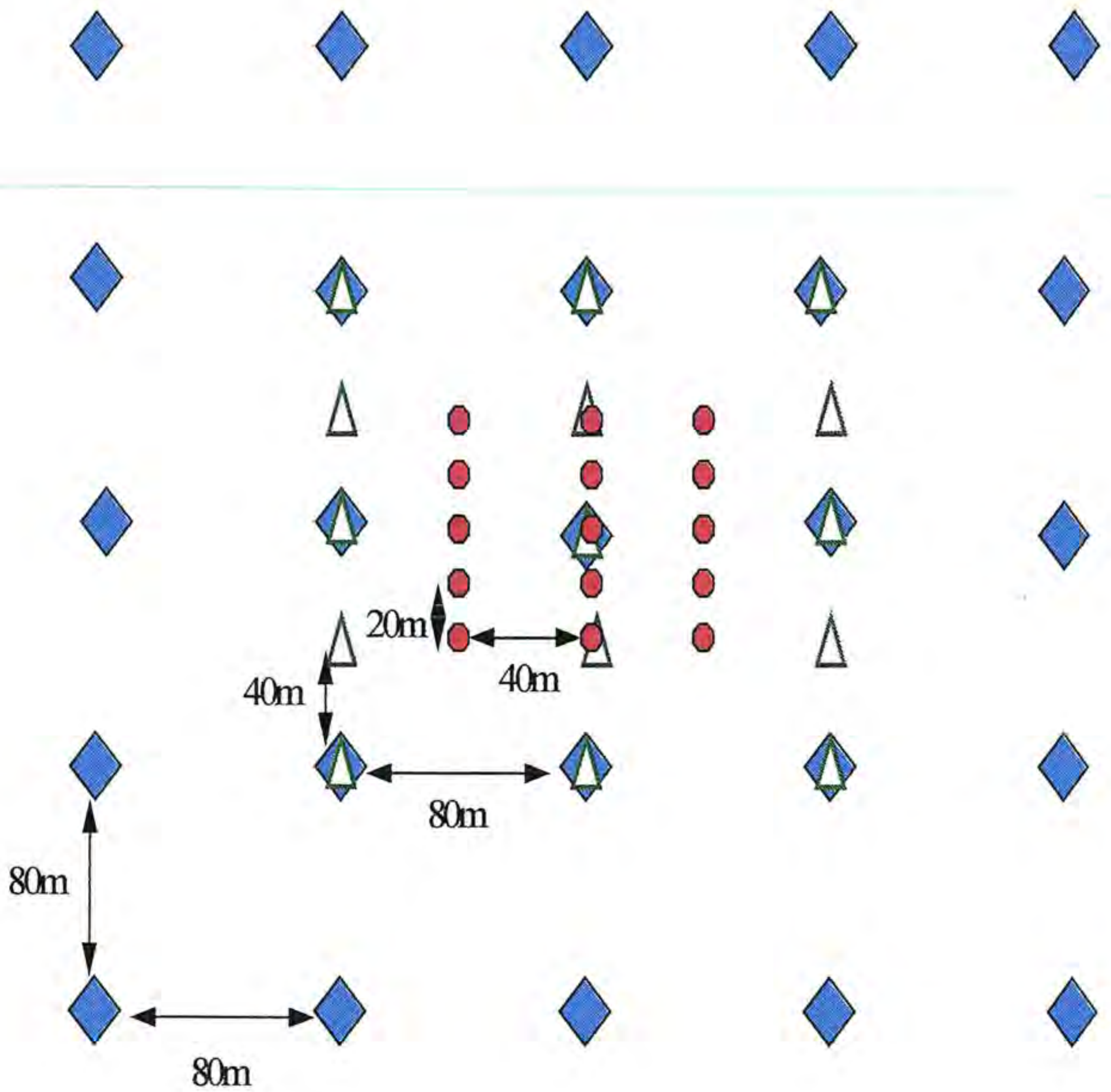
The insecurity of funding and delays in confirmation of NHT funds has jeopardised support from the project's co-funding agencies and corporate sponsorship. The delays in funding advice have also necessitated a stop-start approach to the research and created a lack of continuity of research staff. This has compromised the research and jeopardised the project meeting identified outcomes and milestones.

In the absence of confirmation of 1996-97 and 1997-98 NHT funding, the project's major co-funding agencies (i.e. CALM and the Vertebrate Biocontrol CRC) elected to partially underwrite the project in 1996-97 and 1997-98. This underwriting was to provide continuity of funding and enable the research to proceed towards meeting identified outcomes and milestones and the scheduled completion date.

At the commencement of the 1998-99 financial year, the project was again partially underwritten, in good faith, with the expectation of continued NHT funding. The rationale for underwriting the project was based on the premise that EA/NHT had previously approved the project as a "continuing project" with a completion date of 30 June 2000 and had retrospectively confirmed funding for 1996-97 and 1997-98.

There has been no formal advice of NHT funding for 1998-99. However, in September 1998, CALM received verbal advice from EA that NHT funding would not be provided for 1998-99. The withdrawal of NHT support well after commencement of the 1998-99 financial year has resulted in a significant level of unprogrammed expenditure by CALM.

Figure 3: Integrated trapping grid consisting of 25 "Sheffield" wire cage mammal traps, 15 medium size Elliott traps and 15 pitfall traps. Note, not to scale.

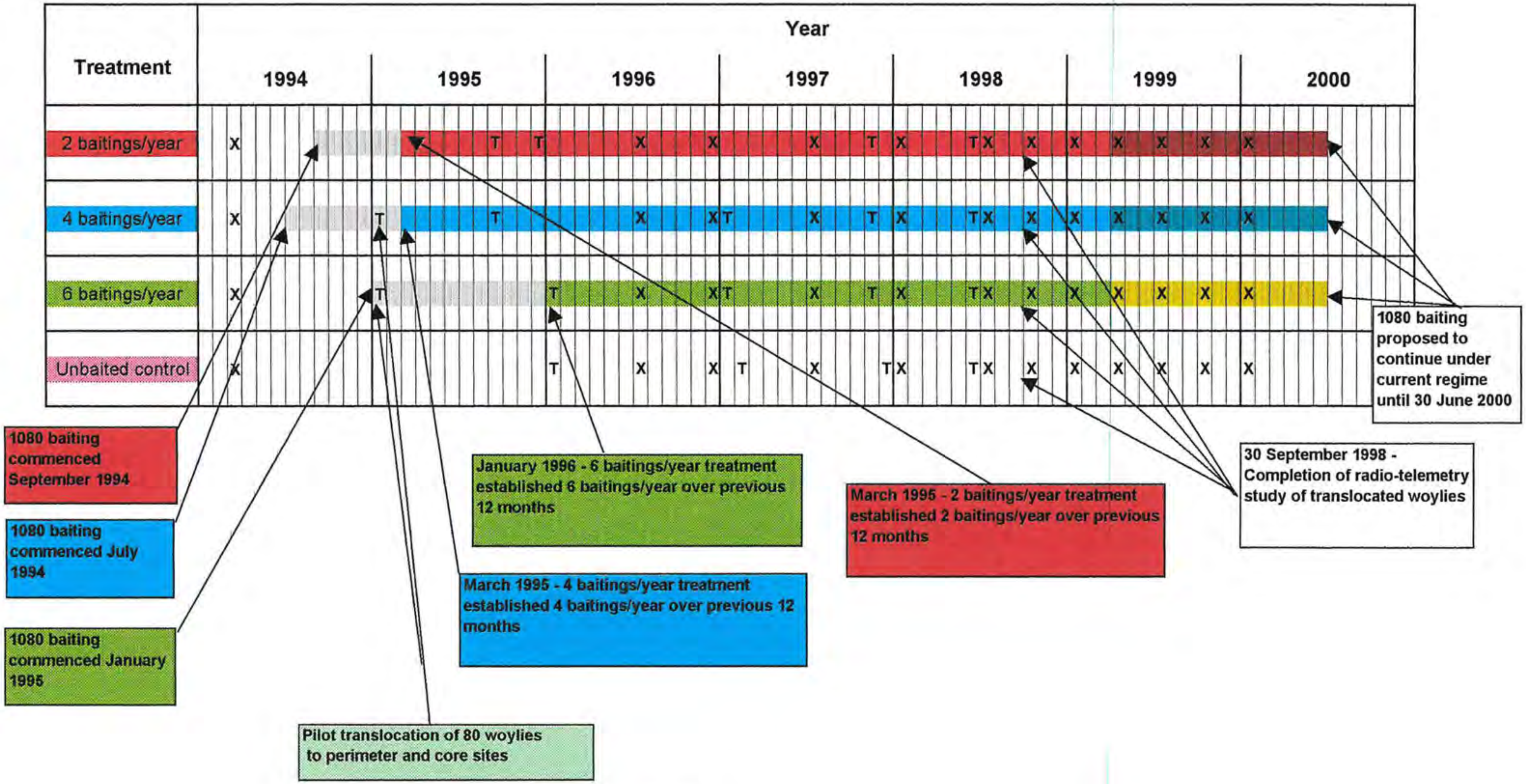


15 pitfall traps at 20m x 40m spacings. Each trap consists of a 20litre plastic bucket and a 7 metre fibreglass flyscreen wire drift fence.

15 Elliott traps at 40m x 80m spacings.

25 wire cage traps at 80m x 80m spacings.

Figure 4: Operation Foxglove - Fox control and research in the northern jarrah forest of southwest Western Australia
History of 1080 baiting and baiting schedule to 30 June 2000;
History of woylie translocations and monitoring;
History of fauna trapping and proposed trapping schedule to 30 June 2000.



T indicates translocation of radio collared woylies
(radio collared sample size maintained through translocations and radio collaring of previously uncollared animals and recruits to the population)

X indicates trapping - wire cage, Elliott and pitfall trips to assess native fauna response to fox density reduction

4. Progress in major activities

4.1. General

The insecurity of funding, and partial underwriting only, has necessitated curtailing progress of some of the proposed activities. Priority has been allocated to:

- radio-telemetry survivorship monitoring of translocated woylies;
- trapping at all grids and transects; and
- sandplot monitoring to derive an index to fox density.

These areas of activity are addressed below. The status of curtailed activities is also identified.

The history of 1080 baiting, showing when baiting commenced for each treatment and when each treatment had received the requisite number of baitings in the preceding 12 months, is shown in figure 4. The baiting regime and trapping schedule for the period to 30 June 2000 is also shown.

4.2. Radio-telemetry monitoring of translocated populations of woylies, *Bettongia penicillata*, and resident populations of the common brushtail possum, *Trichosurus vulpecula*.

4.2.1. Woylie survivorship

In January to March 1995, a pilot study was undertaken involving translocation of 80 woylies to 4 sites. Woylie survivorship was intensively monitored and indicated survivorship was greater at distances of 5km or further from the interface with agricultural land ($P<0.05$, Log-Rank test). Further translocations were carried out in September to October 1995 and October 1995 to January 1996 to 18 sites over all treatments (figures 2 and 4). Supplementary translocations were carried out to maintain the sample size of radio-collared woylies in each treatment. The final translocation was in June 1998. Figure 4 shows the history of translocations to all sites.

Woylie survivorship data were presented in the 1996-97 report for the 78 week monitoring period 1 January 1996 to 30 June 1997. For all sites combined, the 6 baitings per year treatment showed a higher and significantly different level of survivorship from the 2 and 4 baitings per year treatment and the unbaited control ($p<0.05$, Log-Rank test). There was no other significant difference in survivorship.

For sites at 5km or further from agricultural land, the 6 and 4 baitings per year treatments showed higher levels of survivorship, both were significantly different from the 2 baitings per year treatment and the unbaited control ($p<0.05$, Log-Rank test). There was no other significant difference in survivorship.

For sites less than 5km from agricultural land, the 6 baitings per year treatment showed a higher level of survivorship and was significantly different from the 4 baitings per year treatment ($p<0.05$, Log-Rank test). There was no other significant difference in survivorship.

The implications were that 4 and 6 baitings per year were equally sufficient to result in an increased survivorship within the central core of the jarrah forest and a frequency in excess of 6 baitings per year was required at the forest/agricultural land interface.

Subsequent translocations were carried out in 1997 and 1998 (Figure 4). 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

Figures 5 to 7 show survivorship of woylies in all treatments for the 143 week monitoring period 1 January 1996 to 28 September 1998. Survivorship functions are shown commencing from the date all treatments had received the requisite number of baitings in the preceding 12 months and finish at the end of the woylie monitoring study. Completion of the radio-telemetry study co-incided with commencement of the Spring 1998 trapping session when woylie radio-collars were progressively removed.

Data in figures 5 to 7 are shown as Kaplan-Meier survivorship functions modified for staggered entry (Pollock *et al.* 1989a; Pollock *et al.* 1989b)

Figure 5: Kaplan-Meier Survivorship Functions for radio-collared woylies. Northern jarrah forest all sites. For the 143 week period, 1 January 1996 to 28 September 1998

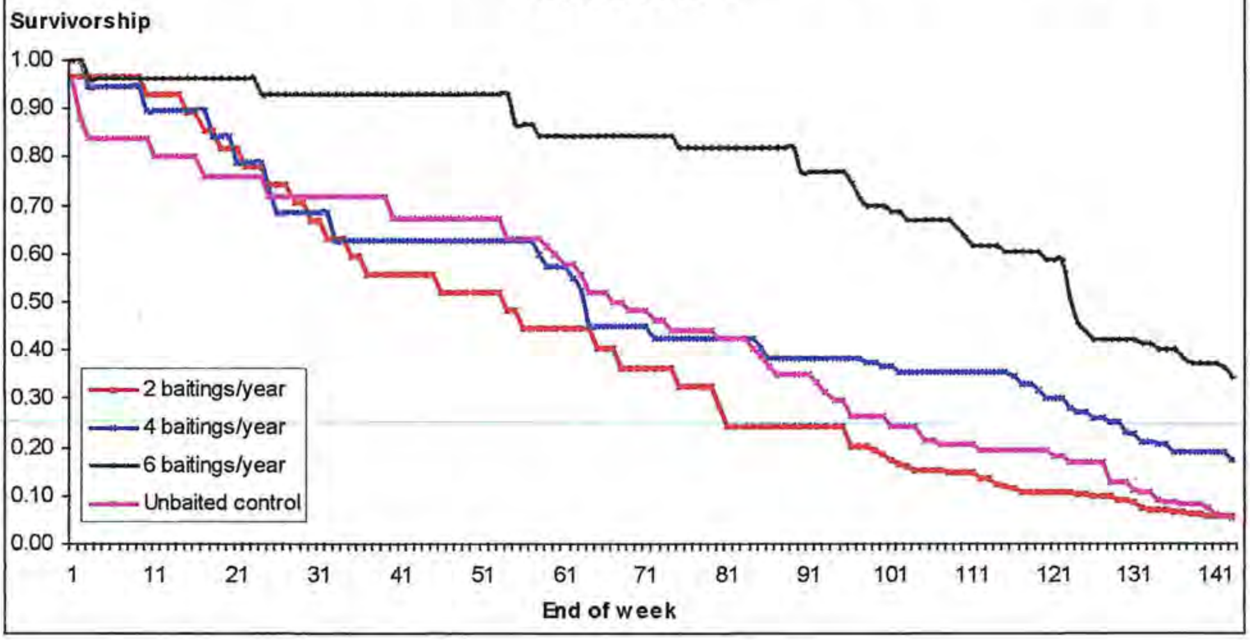


Table 2: **Woylie survivorship at all sites within all treatments (from Kaplan-Meier survivorship functions, figure 5).**

Survivorship is shown at 6 monthly intervals from 29 September 1997 (after 91 weeks monitoring); at 30 March 1998 (after 117 weeks); and at 28 September 1998 (after 143 weeks, the completion of the study).

Common superscript letters indicate no significant difference in survivorship ($p<0.05$, Log-Rank test).

Treatment	Survivorship		
	at week 91 (29 Sept. 1997)	at week 117 (30 Mar. 1998)	at week 143 (28 Sept. 1998)
2 baitings per year	0.24^{a}	0.11^{c}	0.06^{b}
4 baitings per year	0.38^{a}	0.33^{ab}	0.18^{a}
6 baitings per year	0.77	0.60^{a}	0.34^{a}
Unbaited control	0.35^{a}	0.19^{bc}	0.05^{b}

Figure 6: Kaplan-Meier Survivorship Functions for radio-collared woylies. Northern jarrah forest core sites (sites greater than 5km from agricultural land). For the 143 week period, 1 January 1996 to 28 September 1998

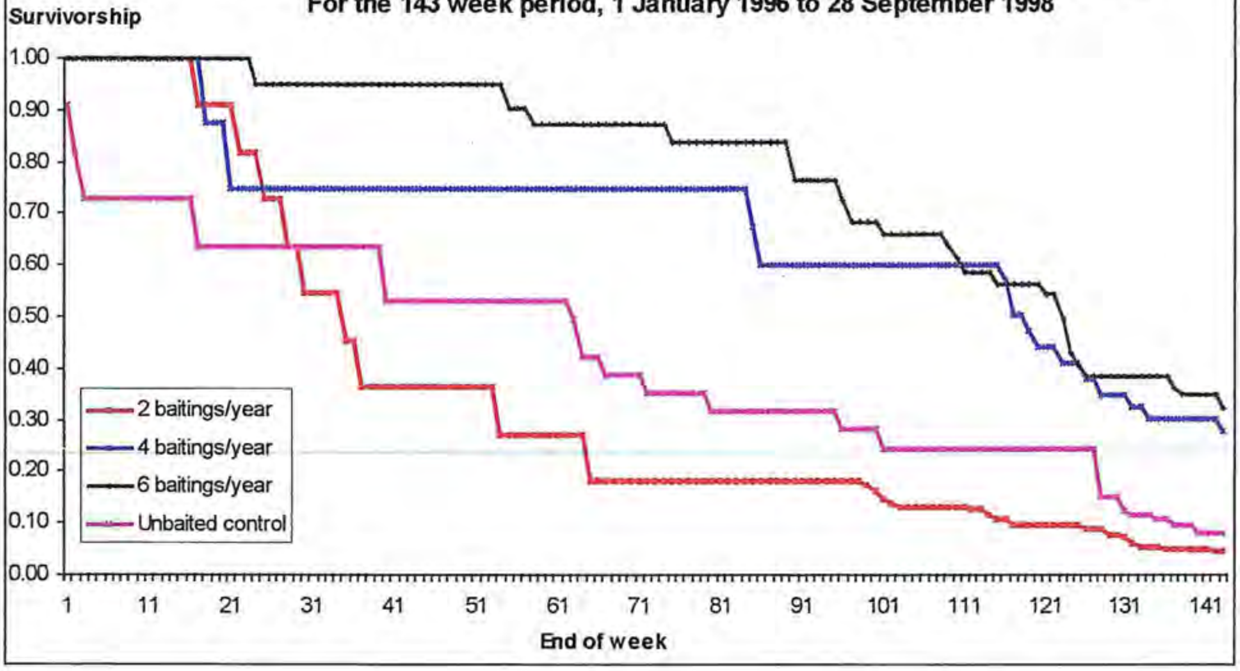


Table 3: Woylie survivorship at sites more than 5km from agricultural land (from Kaplan-Meier survivorship functions, figure 6).

Survivorship is shown at 6 monthly intervals from 29 September 1997 (after 91 weeks monitoring); at 30 March 1998 (after 117 weeks); and at 28 September 1998 (after 143 weeks, the completion of the study).

Common superscript letters indicate no significant difference in survivorship ($p<0.05$, Log-Rank test).

Treatment	Survivorship at week 91 (29 Sept. 1997)	Survivorship at week 117 (30 Mar. 1998)	Survivorship at week 143 (28 Sept. 1998)
2 baitings per year	0.18^{b}	0.10^{c}	0.05^{b}
4 baitings per year	0.60^{ab}	0.51^{ab}	0.28^{a}
6 baitings per year	0.76^{a}	0.56^{a}	0.32^{a}
Unbaited control	0.32^{b}	0.24^{bc}	0.08^{b}

Figure 7: Kaplan-Meier Survivorship Functions for radio-collared woylies.
Northern jarrah forest perimeter sites (sites within 5km of agricultural land).
For the 143 week period, 1 January 1996 to 28 September 1998

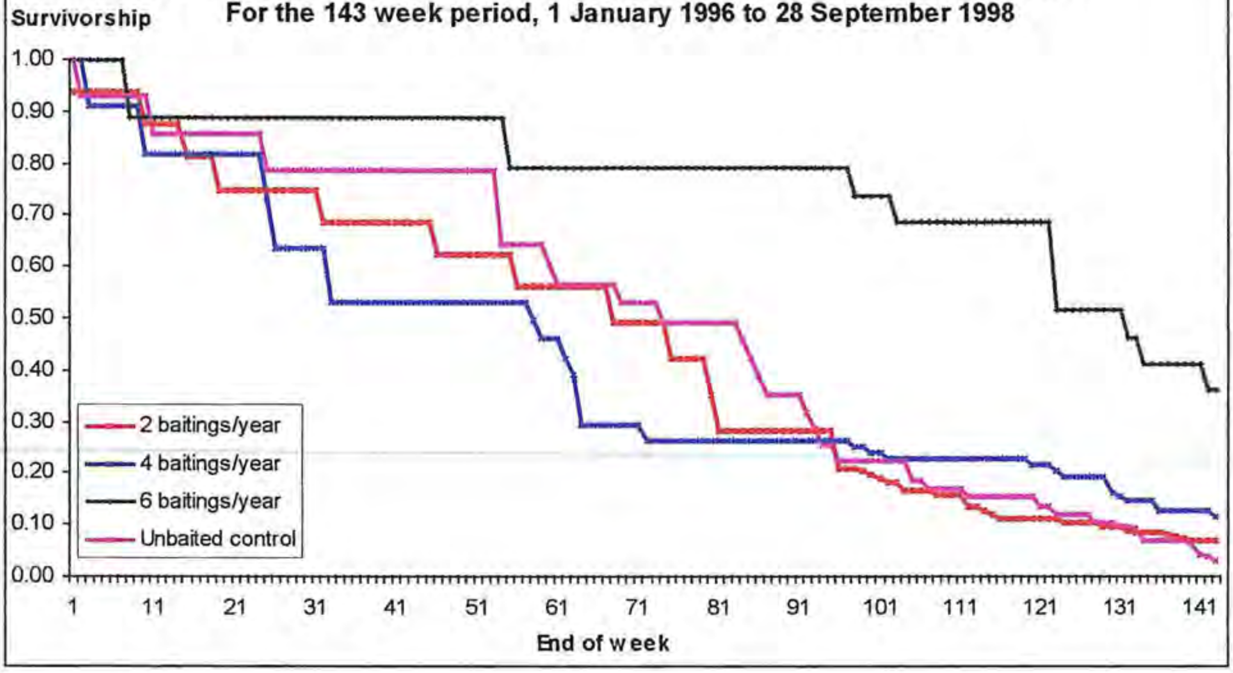


Table 4: Woylie survivorship at sites within 5km of agricultural land (from Kaplan-Meier survivorship functions, figure 7).

Survivorship is shown at 6 monthly intervals from 29 September 1997 (after 91 weeks monitoring); at 30 March 1998 (after 117 weeks); and at 28 September 1998 (after 143 weeks, the completion of the study).

Common superscript letters indicate no significant difference in survivorship ($p<0.05$, Log-Rank test).

Treatment	Survivorship at week 91 (29 Sept. 1997)	Survivorship at week 117 (30 Mar. 1998)	Survivorship at week 143 (28 Sept. 1998)
2 baitings per year	0.28^{a}	0.11^{b}	0.07^{b}
4 baitings per year	0.26^{a}	0.23^{ab}	0.12^{ab}
6 baitings per year	0.76	0.68^{a}	0.36^{a}
Unbaited control	0.32^{a}	0.15^{b}	0.03^{b}

Tables 2, 3 and 4 show survivorship for all sites combined, core sites (sites more than 5km from agricultural land) and perimeter sites (sites within 5km of agricultural land) respectively. The level of survivorship is shown at six monthly intervals after completion of a 91, 117 and 143 week monitoring period.

In all cases (figures 5-7, tables 2-4), the results show a higher level of survivorship for the 6 baitings per year treatment.

All sites combined (perimeter and core sites)

Figure 5 shows survivorship functions for all sites combined. Table 2 shows survivorship at 6 monthly intervals. At week 91, the 6 baitings per year treatment was significantly different from the 2 and 4 baitings per year treatment and the unbaited control ($p<0.05$; Log-Rank test). At week 117 and 143 the 6 baitings per year treatment was significantly different from the 2 baitings per year treatment and the unbaited control ($p<0.05$; Log-Rank test), but not significantly different from the 4 baitings per year treatment ($p>0.05$, $p<0.10$; Log-Rank test).

At week 91, for all sites combined, there was no difference in survivorship between the 4 baitings per year treatment and the unbaited control nor between the 4 and 2 baitings per year treatments. This implies 6 baitings per year is required to achieve a significant difference in survivorship. Similarly, at week 117, there was no significant difference between the 4 baitings per year treatment and the unbaited control, again implying 6 baitings per year is required to achieve a significant difference in survivorship.

Conversely, at week 143, there was no significant difference between the 6 and 4 baitings per year treatments, nor between the 2 baitings per year treatment and the unbaited control. The implication is that 4 baitings per year is sufficient to achieve a significant difference in survivorship.

Interpretation of the survivorship data for perimeter and core sites combined appears to be confounded by within treatment differences, i.e. by differences in survivorship at core and perimeter sites. Therefore, survivorship data have been interpreted for core and perimeter sites separately.

Core sites (sites greater than 5km from agricultural land)

Figure 6 shows survivorship for core sites. Table 3 shows survivorship at 6 monthly intervals. At weeks 91, 117 and 143, the 6 baitings per year treatment was significantly different from the 2 baitings per year treatment and the unbaited control ($p<0.05$; Log-Rank test). At weeks 91, 117 and 143 there was no significant difference between the 6 and 4 baitings per year treatments ($p>0.10$; Log-Rank test).

The 4 baitings per year treatment was not significantly different from the unbaited control at week 91 ($p>0.10$; Log-Rank test) nor at week 117 ($p>0.10$; Log-Rank test). Similarly, the 4 baitings per year treatment was not significantly different from the 2 baitings per year treatment at week 91 ($p>0.05$, $p<0.10$; Log-Rank test). This may imply that 4 baitings per year is insufficient to result in a significant difference in survivorship (from 2 baitings per year and unbaited) at core sites. However, there is consistently no significant difference between the 6 and 4 baitings per treatments ($p>0.10$; Log-Rank test) and the 6 baitings per year treatment is consistently significantly different from the 2 baitings per treatment ($p<0.05$; Log-Rank test) and the unbaited control ($p<0.05$; Log-Rank test). The implication is that 4 baitings per year is sufficient to achieve a significant difference in survivorship at core sites.

Perimeter sites (sites within 5km of agricultural land)

Figure 7 shows survivorship for perimeter sites. Table 4 shows survivorship at 6 monthly intervals. At week 91 and 117 the 6 baitings per year treatment was significantly different from the 2 and 4 baitings per year treatments and the unbaited control ($p<0.05$, Log-Rank test). There was no other significant difference between treatments.

At week 143 the 6 baitings per year treatment was significantly different from the 2 baitings per year treatment and the unbaited control ($p<0.05$, Log-Rank test) and not significantly different from the 4 baitings per year treatment ($p>0.05$; <0.10 Log-Rank test). There was no other significant difference between treatments. The implication is that 6 baitings per year is required to achieve a significant difference in survivorship at perimeter sites.

Implications for baiting regimes

The woylie was selected as an indicator species for the northern jarrah forest study as it 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 data 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 frequency. 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 predation are associated with translocation releases. Similarly, evidence from sandplotting indicated fox presence within the central core of the 6 baitings per year treatment within 2 months of the July 1998 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.

The above baiting regime is recommended as the preferred option for aerial baiting over large areas, however the following cautions apply:

- The woylie survivorship results are not supported by results from trapping (see below);
- Interpreting the woylie survivorship data may be confounded by predation by cats (see below and the 1996-97 report); and
- The woylie survivorship data should be seen as an interim interpretation only - the final analysis of survivorship data was scheduled at 30 June 2000. The anticipated final analysis will use a modified risk set adjusted for right censored animals to eliminate bias in the survivorship estimator and will therefore provide a more accurate estimate of survivorship (see Bunck *et al.* 1995).

It is recommended the amended regime be implemented at completion of the study only if supported by results from trapping data and the modified survivorship analysis. If, and when, the amended baiting regime is implemented, feral cat abundance should be closely monitored.

4.2.2. Attributing predation events

In the period 1 January 1996 to 28 September 1998, there were 184 woylie deaths attributed to predation. Of these, 57 deaths were attributed to fox and 46 to cat predation. Table 5 shows the number of deaths in each treatment and the predator considered responsible. The criteria used to differentiate between deaths attributed to cat and fox predation are as per previously reported (1996-97 report) and shown in table 6.

Table 5: Woylie deaths attributed to predation and the predator considered responsible (1 January 1996 to 28 September 1998).

Treatment	Predator responsible					Total
	Fox (Fox?)(1)	Cat (Cat?)(2)	Fox/Cat?(3)	Unknown(4)	Other (raptor, chuditch, python)	
2 baitings per year	11 (3)	24 (5)	7	9	3	62
4 baitings per year	11	10 (1)	5	9	3	39
6 baitings per year	6	6 (4)	4	5		25
Unbaited control	29 (1)	6 (4)	4	13	1	58
Total	57 (4)	46 (14)	20	36	7	184

(1) (Fox?) refers to deaths attributed to predation and where the predator was considered to be a fox, however evidence from the carcass, the collar and/or the site where the carcass or collar was collected indicated some ambiguity.

(2) (Cat?) refers to deaths attributed to predation and where the predator was considered to be a cat, however evidence from the carcass, the collar and/or the site where the carcass or collar was collected indicated some ambiguity.

(3) Fox/cat? refers to deaths attributed to predation and where the predator was considered to be either fox or cat, however evidence from the carcass, the collar and/or the site where carcass or collar was collected was insufficient to enable differentiation between cat and fox.

(4) Unknown refers to deaths attributed to predation, but predator unable to be identified.

Data previously presented (1996-97 report) supported the assertion that predation by cats may increase in the presence of reduced fox density. The data to September 1998 show a larger number of predation events attributed to cats in the 2 and 4 baitings per year treatments. There is no difference between the number of predation events attributed to cats in the 6 baitings per year treatment and the unbaited control. However, the cat:fox ratio of predation events indicates that cat predation may increase in the presence of fox control (table 7). The results are equivocal and not further discussed (see section 4.1).

Table 7: Ratio of cat to fox predation for predation events of radio collared woylies, northern jarrah forest, for the period 1 January 1996 to 28 September 1998. The ratio is derived from predation events where there was thought to be no ambiguity as to the predator responsible

Treatment	Ratio of cat:fox predation events
2 baitings per year	2.18
4 baitings per year	0.91
6 baitings per year	1.00
Unbaited control	0.21

Table 6: **Diagnostic features used to differentiate between cat and fox kills of the brush-tailed bettong, *Bettongia penicillata*, at the northern jarrah forest research sites. Table modified from 1996-97 report.**

Predator	Features at kill site or on carcass	Additional comments
Fox	Carcass can be entire or only partially recovered. Often cached, and if so, will be buried under soil or other debris with evidence of digging or excavation under and/or beside the cached carcass. If the carcass is dismembered, limbs may be present at the site, often with evidence of chewing and crushing. If abdominal cavity opened, stomach and intestines have usually been removed and presumably eaten or cached elsewhere. Abdominal or thoracic organs may be absent or present. Head can be entire or crushed. Condition of radio-collar can range from undamaged (can still be in place on carcass or undamaged and removed from carcass), to grossly compressed and mis-shapen with numerous teeth marks. If teeth marks are present they are almost invariably large (see additional comments) and indicative of canid teeth. Noticeable odour of fox or fox urine.	Not all features are present at every kill site/recovered carcass There is some evidence to suggest that when cubs are present (September to February), smaller teeth marks are also evident on collar. If the collar only is recovered there is usually no attempt to attribute the death to predation or to a specific predator. Death is usually only attributed to predation if there has been a very short time between detecting the last live signal and retrieving the radio collar. Teeth marks alone are not used to attribute death to a predator unless there is other strong evidence to do so, for example, if the retrieved collar was cached, if it was at a fox den site and the woylie was known to be alive within the previous 24 hours.
Cat	Carcass can be entire or only partially recovered. If cached, will be buried or only partially buried, usually under leaf litter with no evidence of digging or excavation under and/or beside the cached carcass. If abdominal cavity open, stomach and intestines usually remaining (either *in situ* or beside the carcass). Abdominal and thoracic organs may be removed. Skin often peeled back from limbs and body, flesh removed (presumably eaten). Head may be attached to body or detached, often with brain removed. Condition of radio-collar as for fox, difficult to distinguish between cat and fox teeth marks. Noticeable cat urine odour.	Carcasses with skin peeled back and flesh removed may also be characteristic of raptor predation (J.A. Friend pers. com.). Additional evidence is required to differentiate between cat and raptor predation. The position of the retrieved carcass may be in the open, straddled across a log or have sections on either side of a log (all implicating raptor) as opposed to concealed or partially concealed under shrubs, or under or in a log (implicating cat more than raptor). As for foxes, if only the collar is recovered, death cannot be attributed to predation without supporting evidence.

Note: Early detection of mortality events is critical if information is required on the cause of death. Confidence in determining the cause of death and the predator responsible for a predation event decreases with increasing time between detecting the last live signal and when the carcass or collar is retrieved. Intensive monitoring and use of movement sensitive mortality transmitters (i.e. transmitters with two possible modes) have been used to maximise the possibility of determining the cause of death and attributing predation events to a predator species. Mortality collars used have a "live mode" pulse rate of 50-55 beats per minute (bpm) and a "dead" or "mortality mode" pulse rate of 100-110 bpm. A 2½ hour period is required to trigger mortality mode.

4.2.3. Survivorship of the common brushtail possum

The 1996-97 report recorded no difference between treatments for survivorship of radio collared common brushtail possums. The lack of a detectable response indicated that fox predation was not limiting common brushtail possum abundance. However, as per the 1996-97 report, the lack of a detectable response may also be attributed to the small sample size and the absence of juvenile and sub-adult possums in the monitored sample. In the period to September 1998, the sample size of radio collared possums was increased and a breakaway collar, suitable for use on juvenile and sub adult animals, was developed.

Survivorship monitoring of the common brushtail possum has been curtailed (see section 4.1). 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 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 an additional 12 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 1998-99 detailed operational plan. Frequency of trapping was increased to allow appropriate analysis of trapping data (Mark-Recapture analysis using the Robust Model, see section 2.2.4.).

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 are shown (figures 8 – 12) as percentage capture success transformed to give an index to density (Caughley 1977).

The results should be seen as interim trends, derived from crude (percentage capture) estimates of density. The percentage capture values have been transformed to give an index to density because of the non linear relationship between capture rate and density at capture frequencies above 0.2 (Caughley 1977).

Figure 8 shows the derived index to density for *Dasyurus geoffroii*, *Trichosurus vulpecula* and *Isoodon obesulus* for each treatment for each of the three most recent trapping sessions. The index was derived from the average daily capture success at each trapping grid and transect.

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

what if data from summer 94/95 included

Figures 9 – 12 show the derived index to density for *Dasyurus geoffroii*, *Trichosurus vulpecula*, *Isoodon obesulus* and *Antechinus flavipes* for the most recent trapping session (Summer 1998-99). Data are shown for each trapping grid in each treatment. The index was derived from the average daily capture success at each trapping grid.

The trapping data show no significant difference in density between treatments.

Figure 8a: Density estimates (index to density), *Dasyurus geoffroii*, all treatments

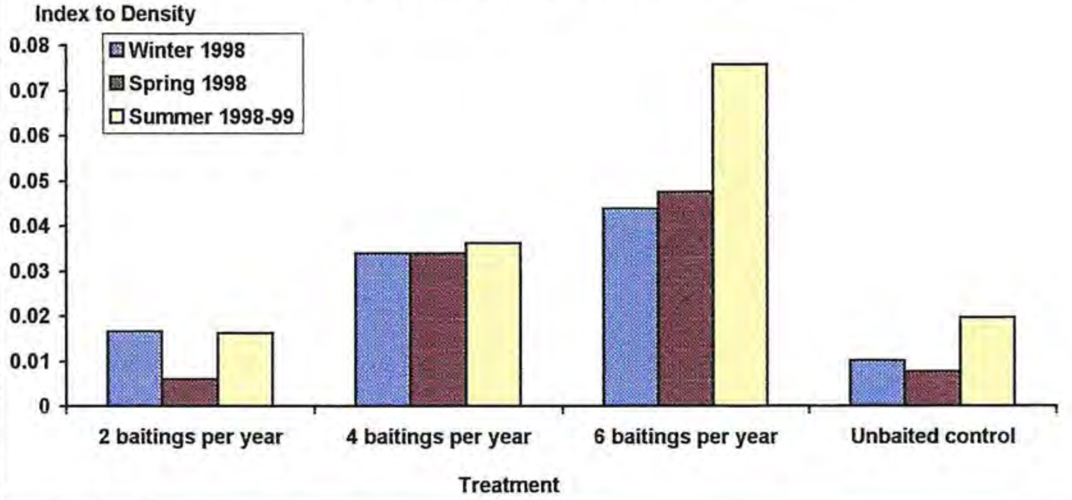


Figure 8b: Density estimates (index to density), *Trichosurs vulpecula*, all treatments

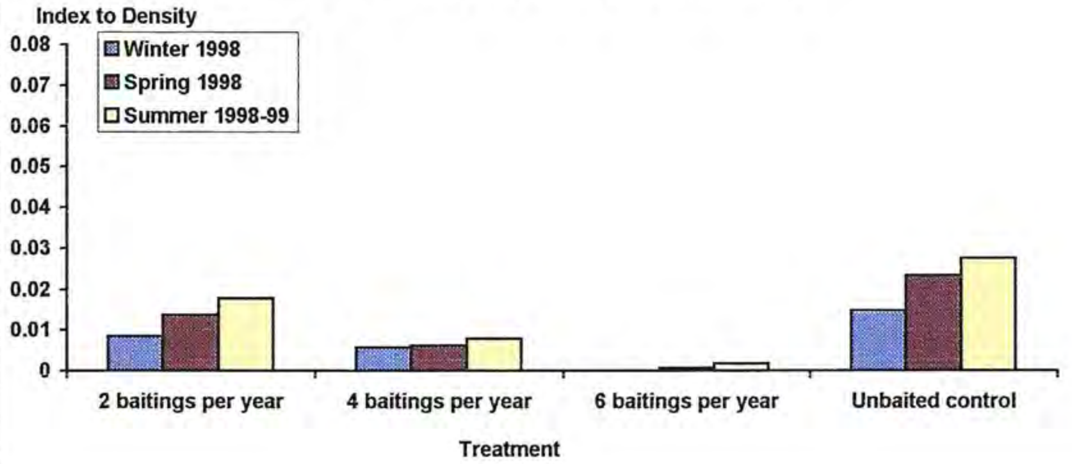
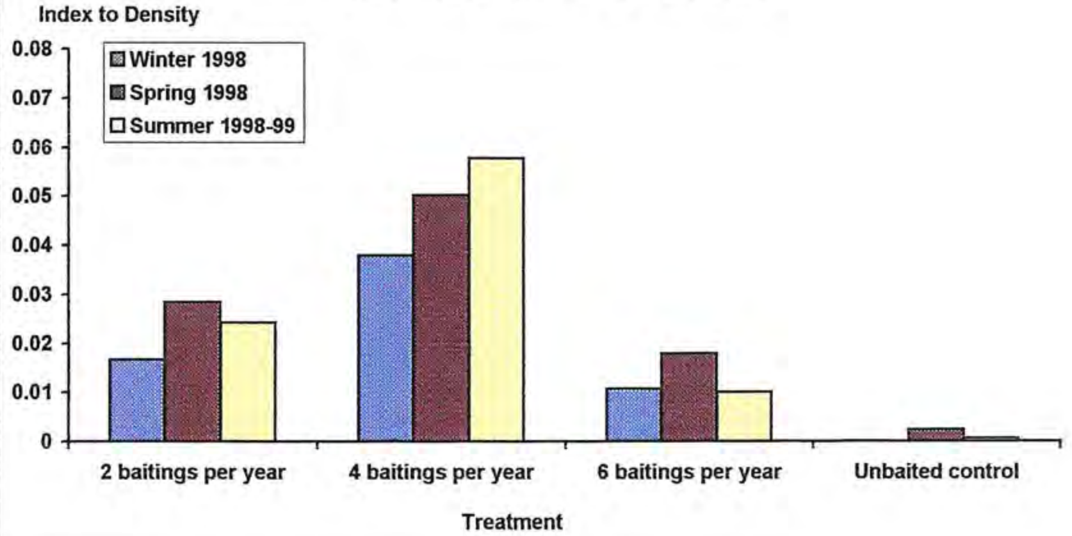


Figure 8c: Density estimates (index to density), *Isoodon obesulus*, all treatments



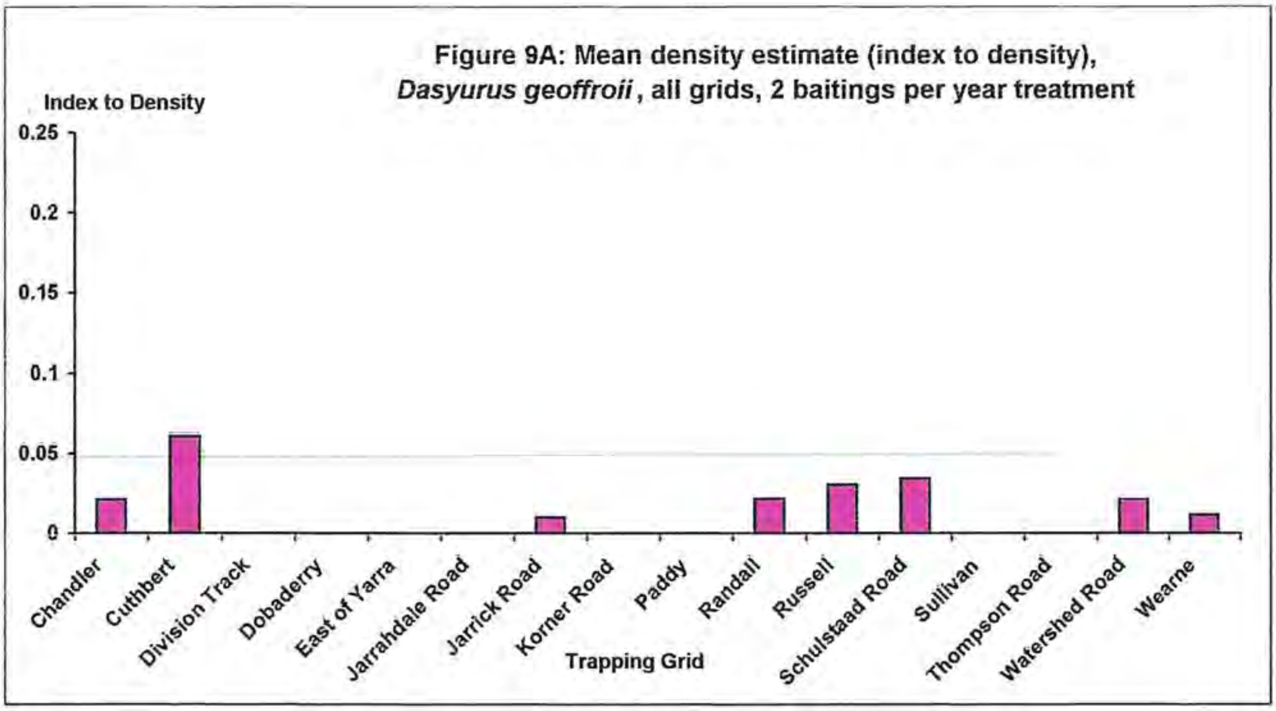


Figure 9A: Mean density estimate (index to density),
Dasyurus geoffroii, all grids, 2 baitings per year treatment
Index to Density
0.25
0.2
0.15
0.1
0.05
0
Chandler
Cuthbert
Division Track
Dobaderry
East of Yarra
Jarrahdale Road
Jarrick Road
Korner Road
Paddy
Randall
Russell
Schulstaad Road
Sullivan
Thompson Road
Watershed Road
Wearne
Trapping Grid

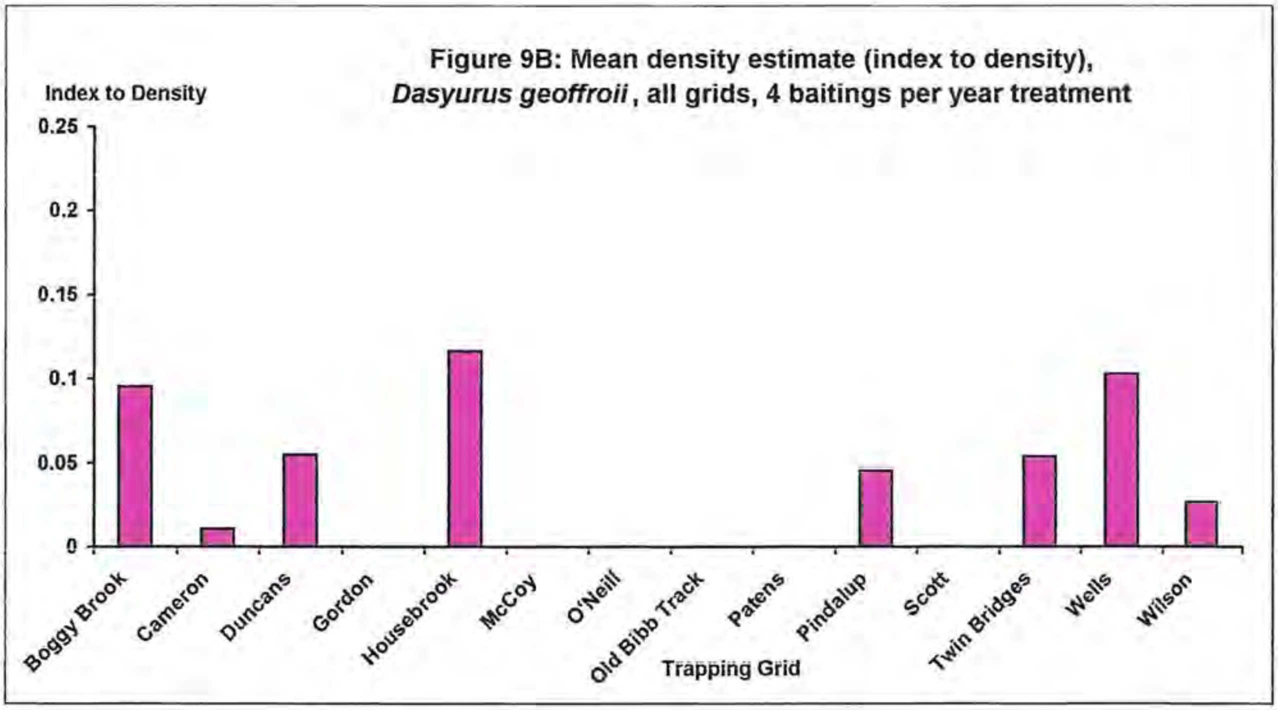


Figure 9B: Mean density estimate (index to density),
Dasyurus geoffroii, all grids, 4 baitings per year treatment
Index to Density
0.25
0.2
0.15
0.1
0.05
0
Boggy Brook
Cameron
Duncans
Gordon
Housebrook
McCoy
O'Neill
Old Bibb Track
Patens
Pindalup
Scott
Twin Bridges
Wells
Wilson
Trapping Grid

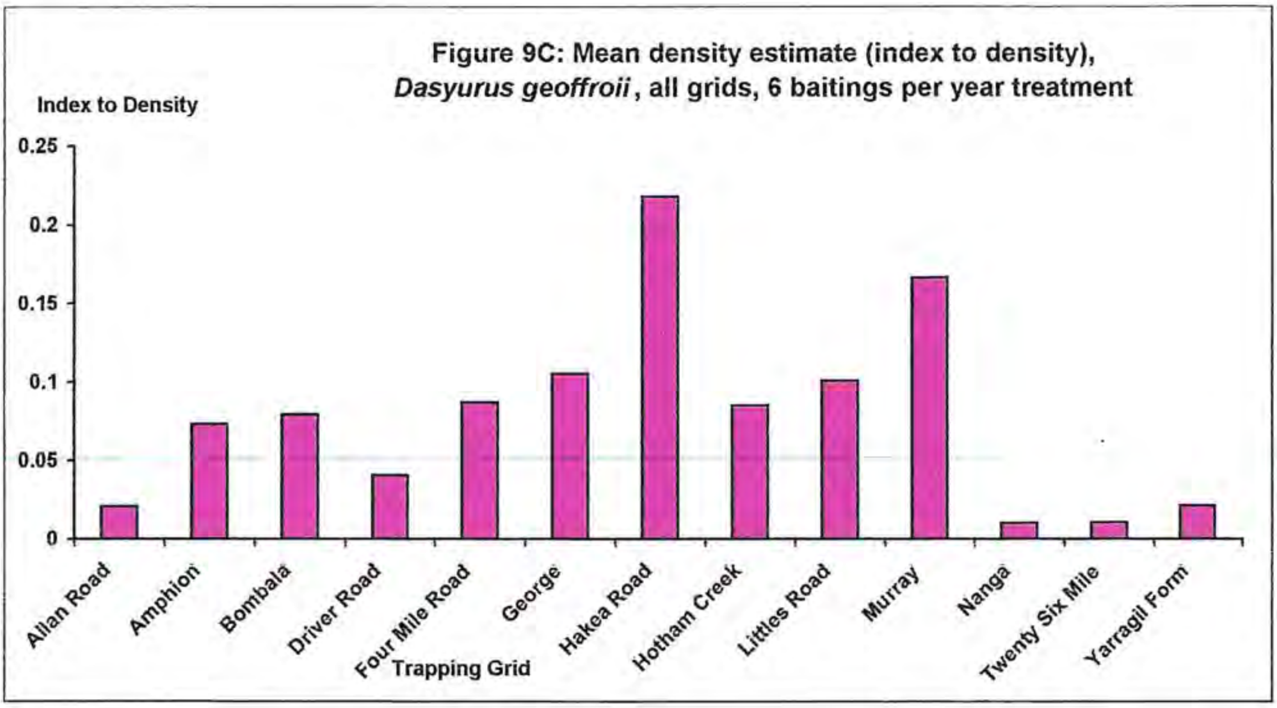


Figure 9C: Mean density estimate (index to density),
Dasyurus geoffroii, all grids, 6 baitings per year treatment
Index to Density
0.25
0.2
0.15
0.1
0.05
0
Allan Road
Amphion
Bombala
Driver Road
Four Mile Road
George
Hakea Road
Hotham Creek
Littles Road
Murray
Nanga
Twenty Six Mile
Yarragil Form
Trapping Grid

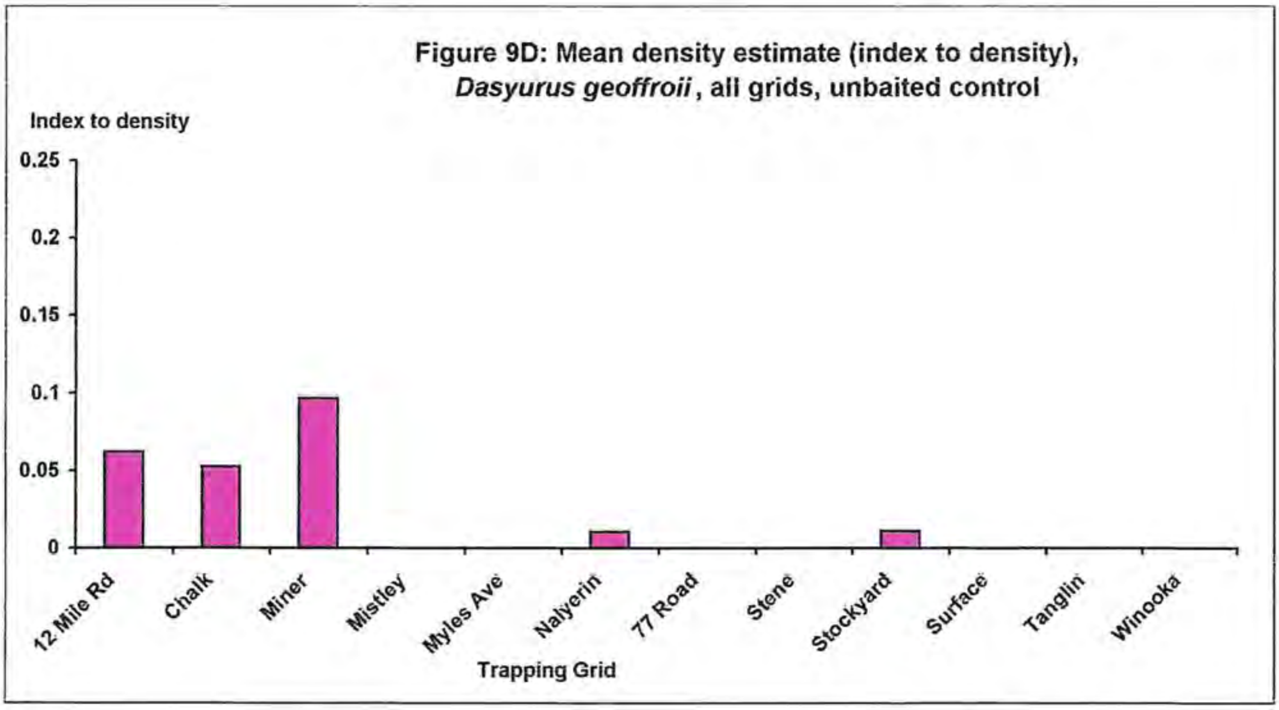


Figure 9D: Mean density estimate (index to density),
Dasyurus geoffroii, all grids, unbaited control
Index to density
0.25
0.2
0.15
0.1
0.05
0
12 Mile Rd
Chalk
Miner
Mistley
Myles Ave
Nalyerin
77 Road
Stene
Stockyard
Surface
Tanglin
Winooka
Trapping Grid

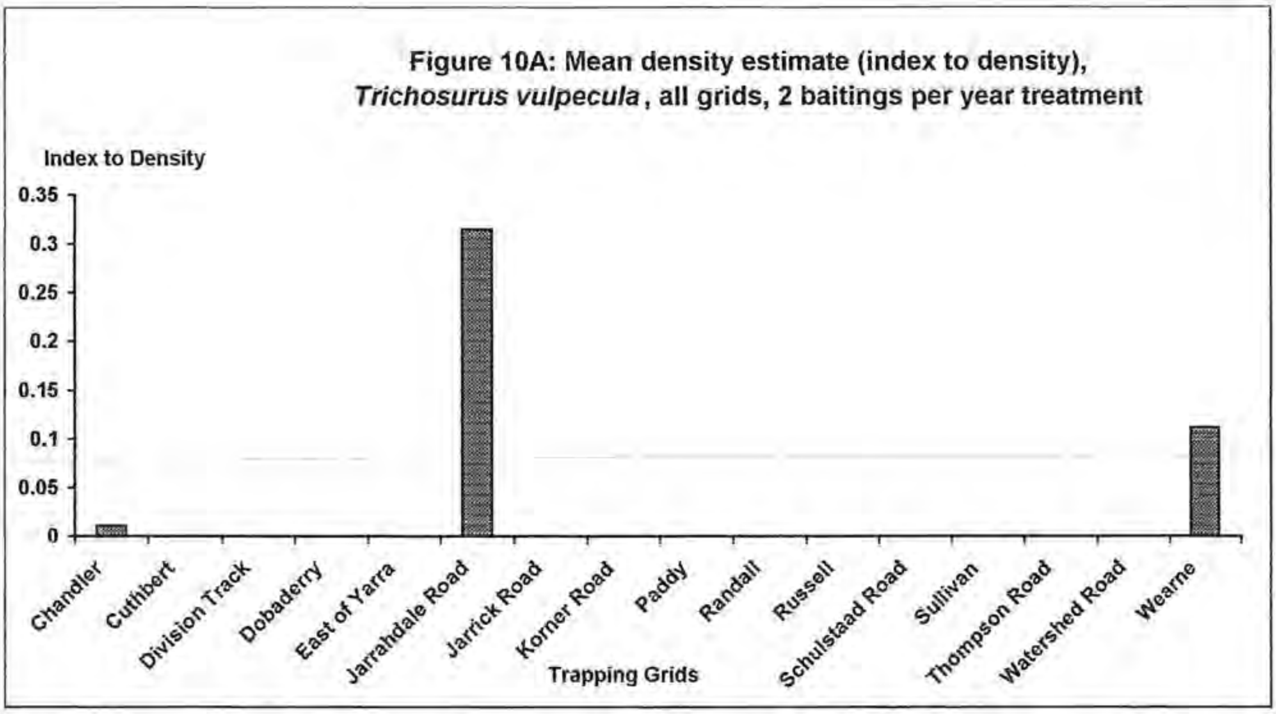


Figure 10A: Mean density estimate (index to density), Trichosurus vulpecula, all grids, 2 baitings per year treatment
Index to Density
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Chandler
Cuthbert
Division Track
Dobaderry
East of Yarra
Jarrahdale Road
Jarrick Road
Korner Road
Paddy
Randall
Russell
Schulstaad Road
Sullivan
Thompson Road
Watershed Road
Wearne
Trapping Grids

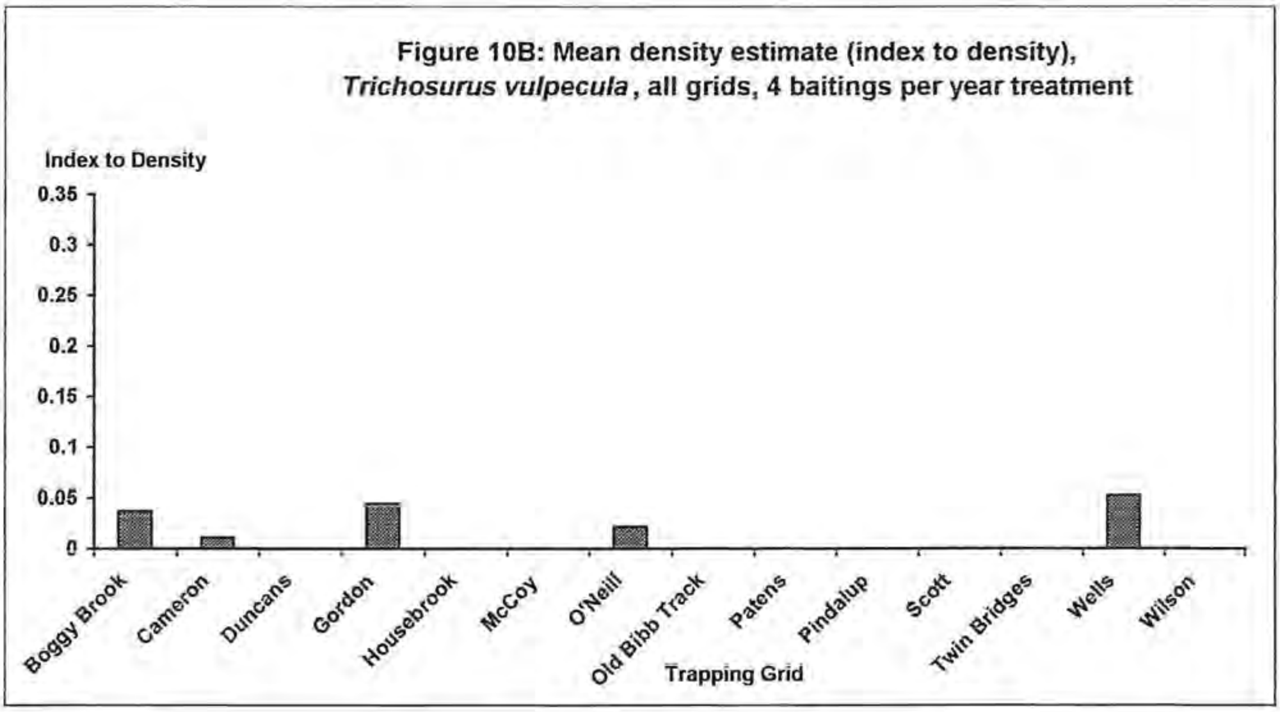


Figure 10B: Mean density estimate (index to density), Trichosurus vulpecula, all grids, 4 baitings per year treatment
Index to Density
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Boggy Brook
Cameron
Duncans
Gordon
Housebrook
McCoy
O'Neill
Old Bibb Track
Patens
Pindalup
Scott
Twin Bridges
Wells
Wilson
Trapping Grid

Figure 10C: Mean density estimate (index to density), *Trichosurus vulpecula*, all grids, 6 baitings per year treatment

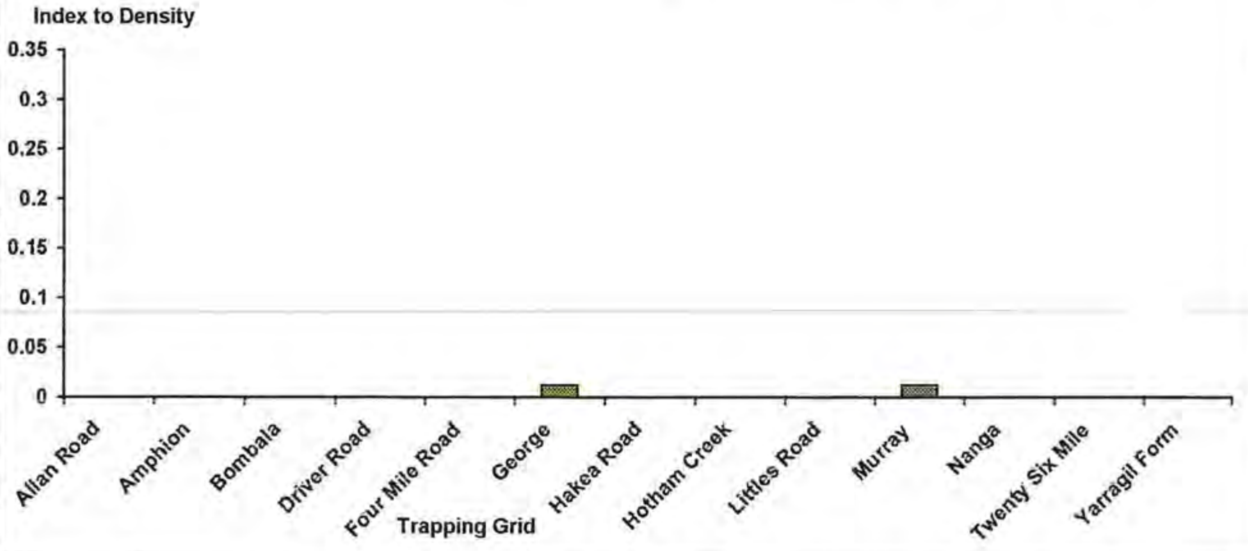


Figure 10D: Mean density estimate (index to density), *Trichosurus vulpecula*, all grids, unbaited control

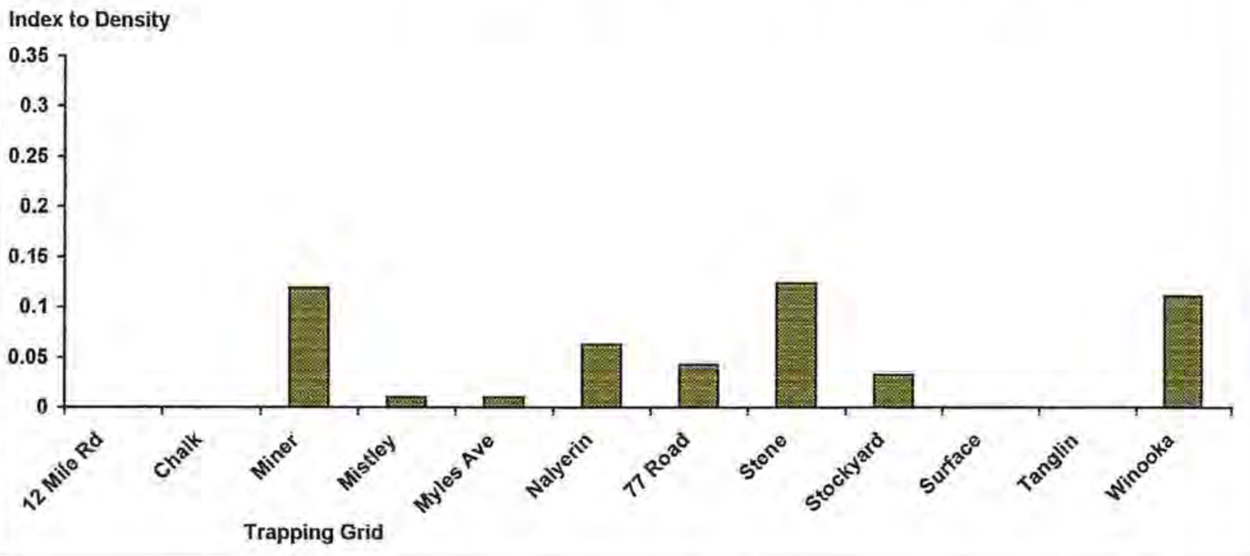


Figure 11A: Mean density estimate (index to density), *Isoodon obesulus*, all grids, 2 baitings per year treatment

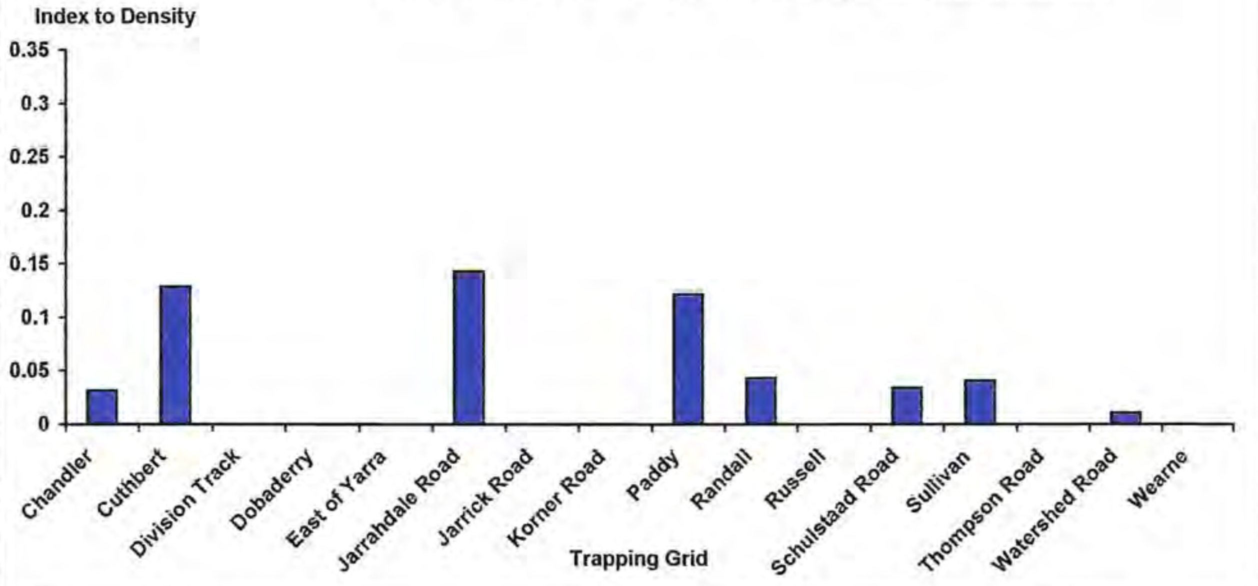
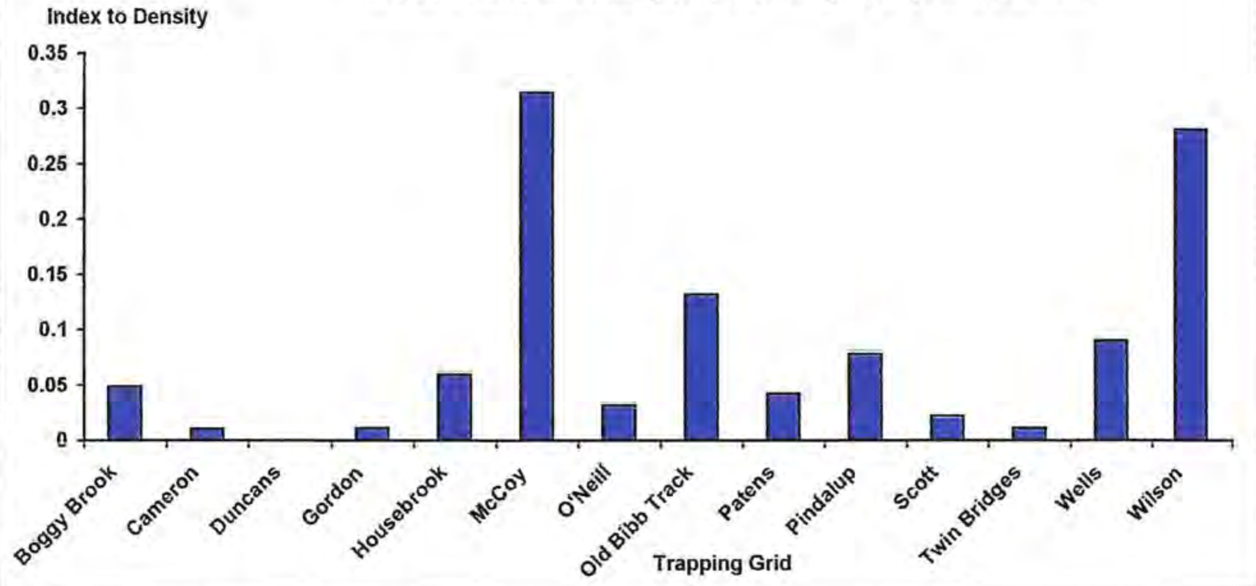


Figure 11B: Mean density estimate (index to density), *Isoodon obesulus*, all grids, 4 baitings per year treatment



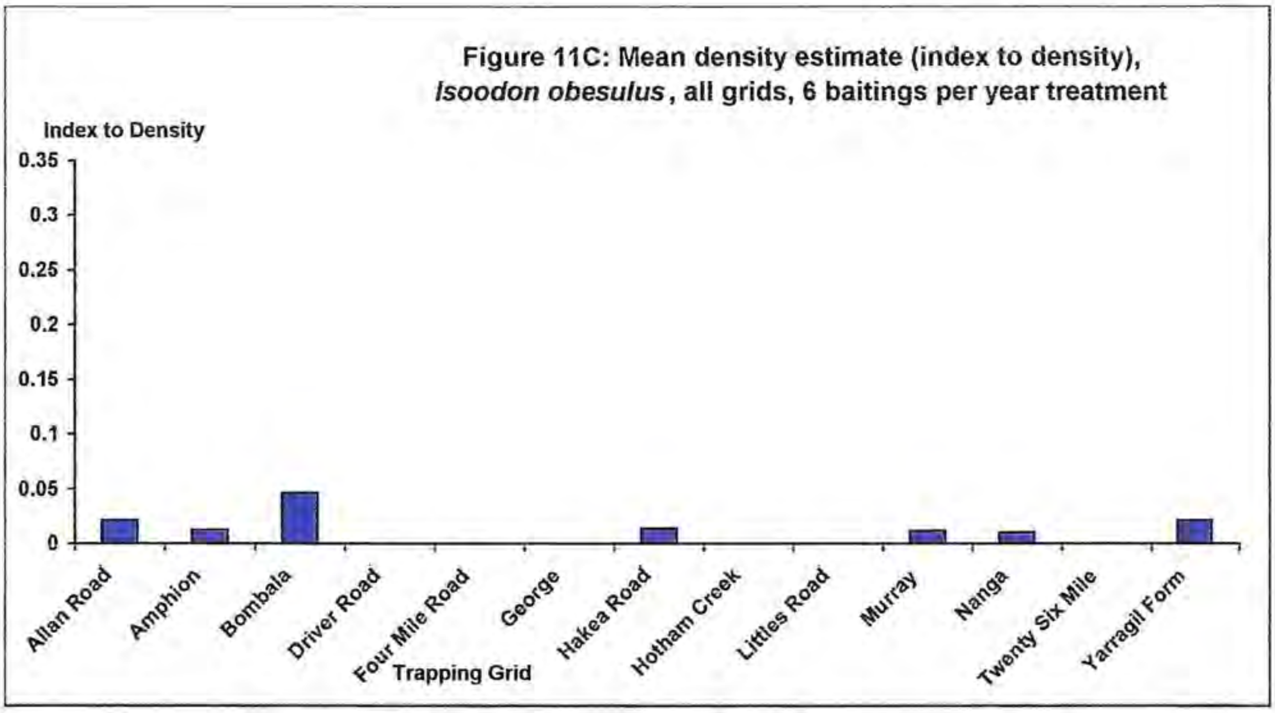


Figure 11C: Mean density estimate (index to density), *Isoodon obesulus*, all grids, 6 baitings per year treatment
Index to Density
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Allan Road
Amphion
Bombala
Driver Road
Four Mile Road
George
Hakea Road
Hotham Creek
Littles Road
Murray
Nanga
Twenty Six Mile
Yarragil Form
Trapping Grid

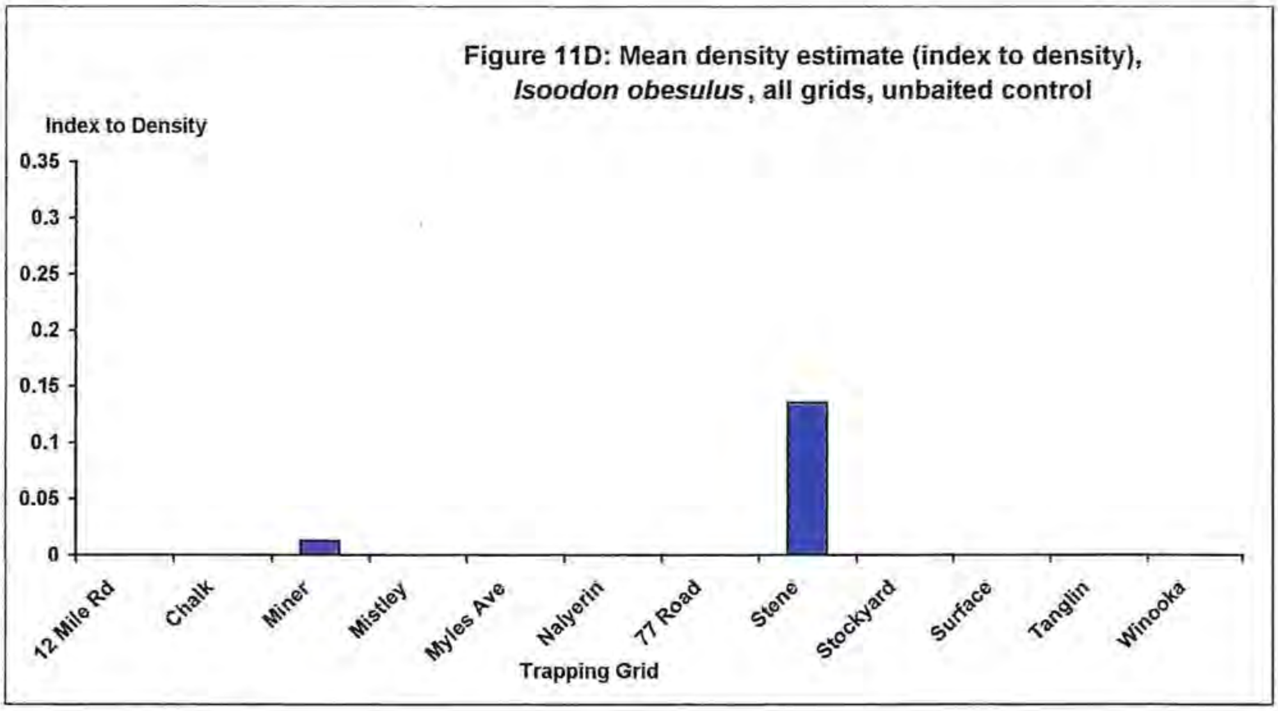


Figure 11D: Mean density estimate (index to density), *Isoodon obesulus*, all grids, unbaited control
Index to Density
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
12 Mile Rd
Chalk
Miner
Mistley
Myles Ave
Nalyerin
77 Road
Stene
Stockyard
Surface
Tanglin
Winooka
Trapping Grid

Figure 12A: Mean density estimate (index to density), *Antechinus flavipes*, all grids, 2 baitings per year treatment

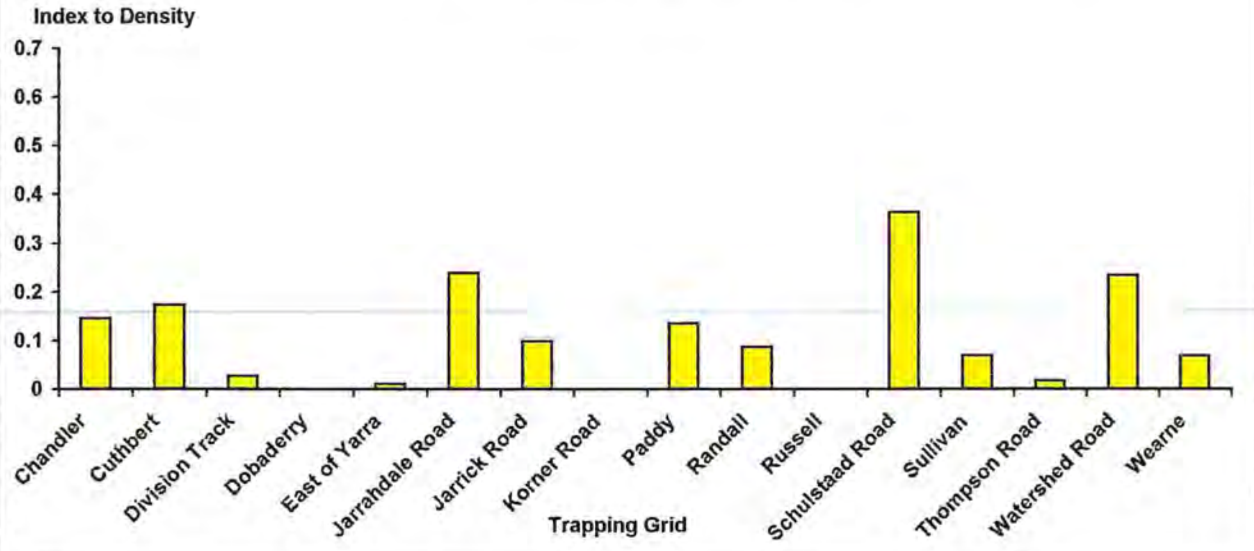


Figure 12B: Mean density estimate (index to density), *Antechinus flavipes*, all grids, 4 baitings per year treatment

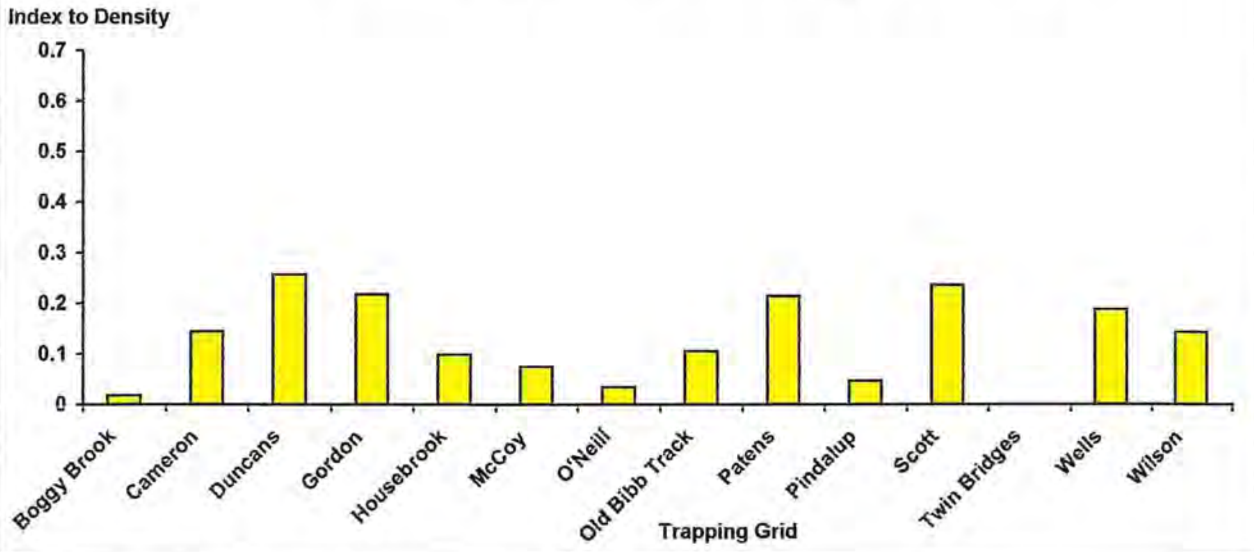


Figure 12C: Mean density estimate (index to density), *Antechinus flavipes*, all grids, 6 baitings per year treatment

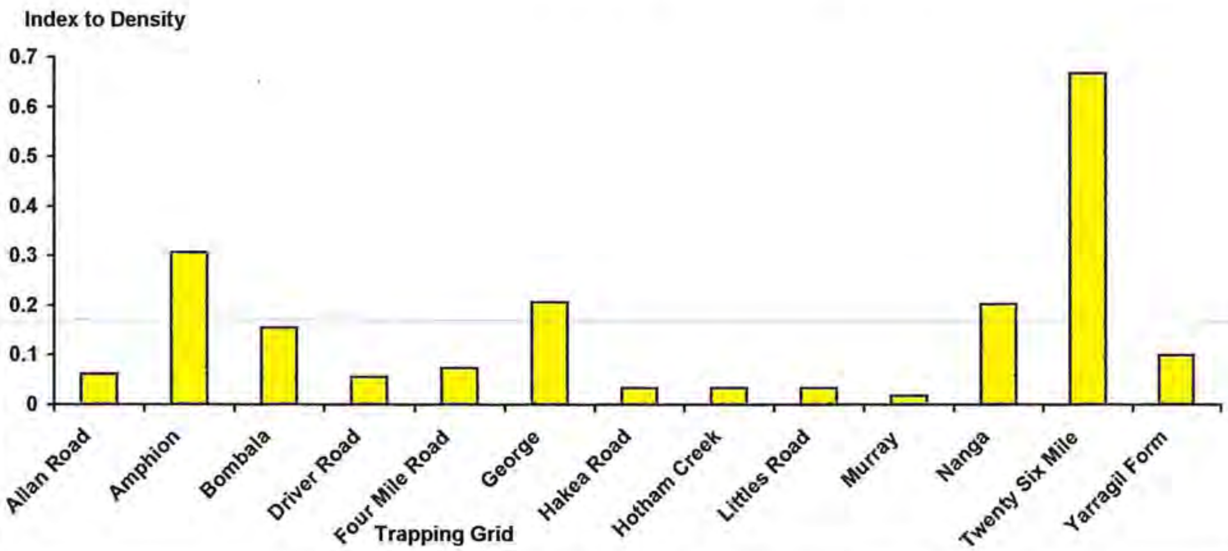
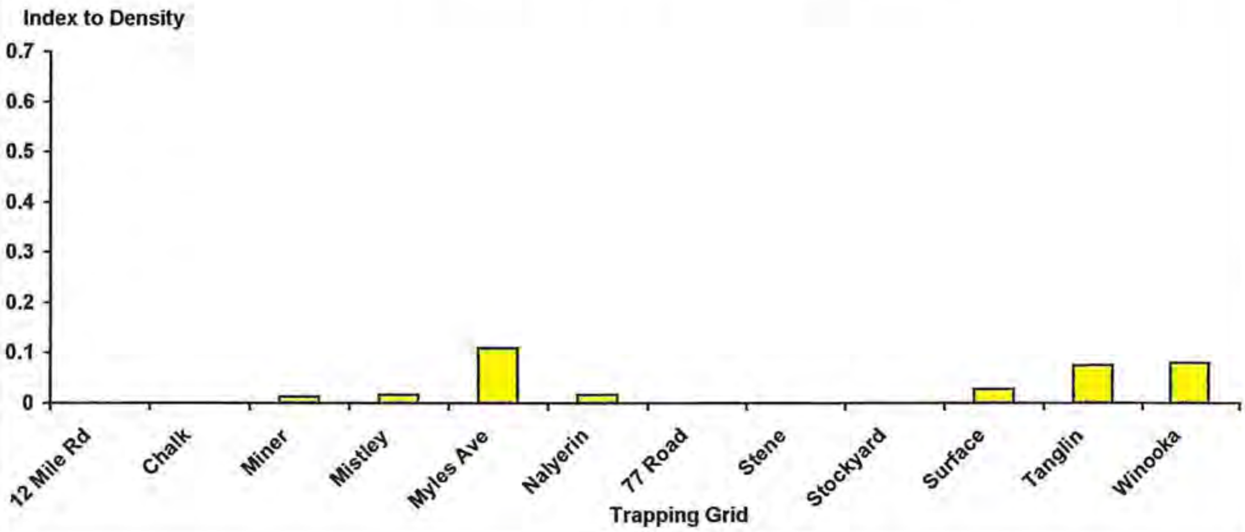


Figure 12D: Mean density estimate (index to density), Antechinus flavipes, all grids, unbaited control



Is fox predation limiting native fauna abundance in the northern jarrah forest?

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 data to date indicate no apparent response to fox control.

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 that a 5 to 7 year period would be required for a response to be detected through conventional trapping techniques. 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, and use of inappropriate techniques as a result of the premature analysis, may well lead to a false conclusion. In the case of the northern jarrah forest, premature analysis of trapping data may lead to acceptance of the null hypothesis and result in a Type 2 error. If the null hypothesis is accepted, i.e. that there is no difference in fauna abundance between treatments, 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.

Caughley and Gunn (1996) and Kinnear *et al.* (1998) highlighted the consequences of a Type 2 error, and acceptance of the null hypothesis (H_0). A more appropriate conclusion is to not reject the null hypothesis (Kinnear *et al.* 1998).

The consequences of not allowing sufficient time for a response to occur and be detected, may be further compounded by premature interpretation of site specific habitat variables.

Data on *Trichosurus vulpecula* show the highest density at the long unburnt grid within the 2 baitings per year treatment (Jarrahdale Road Grid, 62 years since last fire, figure 10b). Three grids from the unbaited control (figure 10d) show the next highest, and comparable *T. vulpecula* densities. Two of these grids are dominated by *Eucalyptus wandoo* (wandoo), the third is unlogged and dominated by *E. wandoo* and *Eucalyptus marginata* (jarrah). 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* and *Antechinus flavipes* (figures 11 and 12 respectively).

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. Increased abundance of feral cats has been associated with reductions in fox density at Heirisson Prong, Western Australia (D. Risbey, personal communication). There is evidence to suggest this may also be the case in the northern jarrah forest (see previous section and the 1996-97 report), i.e. increased predation by cats may be compensating for a reduced level of fox predation. 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.

There have been few experimental studies to test whether fox predation is limiting abundance of small to medium size mammal populations. Two landmark studies stand out: the Western Australian 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.

Previous reports and agreed outcomes identified the requirement to monitor fauna response for 5-7 years post commencement of 1080 baiting. Completion of the scheduled field work would enable appropriate analysis of trapping data and completion of site specific habitat data collection and final analysis.

4.4. Twice yearly spotlighting of 4 transects within each treatment to supplement trapping data above.

Spotlight monitoring was carried out twice yearly until March 1998. Spotlight monitoring was curtailed in September 1998 (see section 4.2).

At March 1998, there was no significant difference in the number of sightings per km/hr. As for the results from trapping, lack of a detectable response may be a function of insufficient time since commencement of fox control.

4.5. Derivation of an annual index to fox density through the use of sandplots.

Fox density estimates derived from sandplotting are shown in Table 8 and figures 13 and 14. Data are shown for estimates derived in Spring 1997 and 1998.

Estimates are derived in September/October when fox home range boundaries are 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).

Within Australia, reported fox density estimates vary enormously. Saunders *et al.* (1995) listed 7 studies reporting fox density estimates in non-urban environments. Density estimates ranged from 0.2 to 7.2 foxes per square kilometre. There was no consistency in techniques used to derive these estimates.

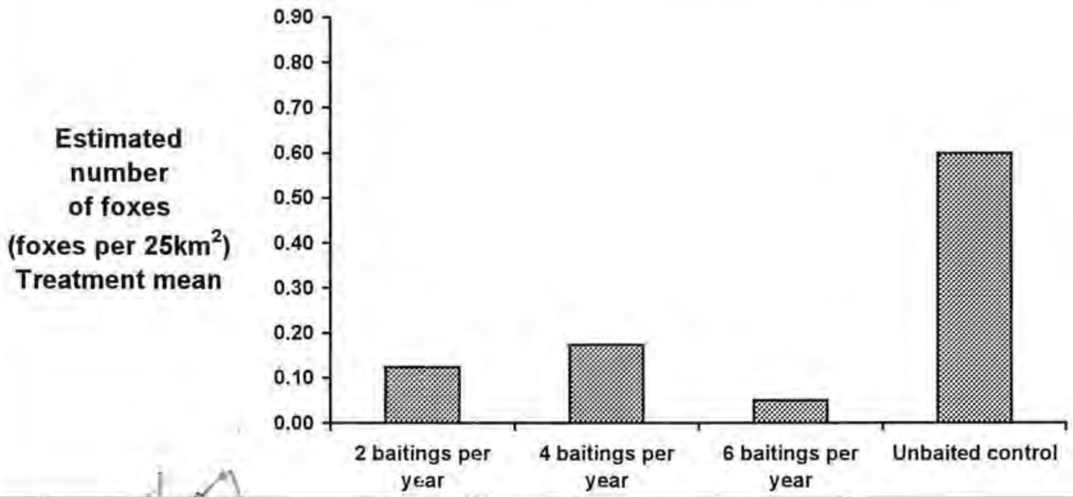
The northern jarrah forest data are not comparable with those reported by Saunders *et al.* (1995) because of the difference in techniques used and different time of year when estimates were derived.

The results from the northern jarrah forest indicate fox density increased across all baited treatments between 1997 and 1998 (Table 10, figures 13 and 14). Density in the unbaited treatment remained stable.

Table 10: Northern jarrah forest estimates of fox density from sandplots, September 1997 and September 1998. Estimate is a treatment mean.

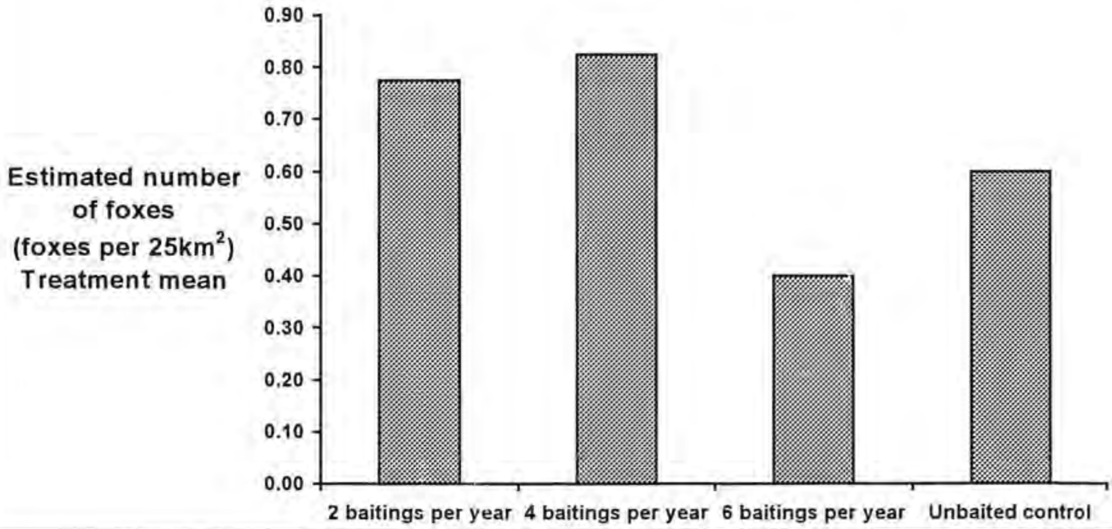
Treatment	Estimated number of foxes/25km² sandplot grid (n) = number of sandplot grids	
	1997	1998
2 baitings per year	0.13 (5)	0.78 (5)
4 baitings per year	0.18 (4)	0.83 (4)
6 baitings per year	0.05 (4)	0.40 (4)
Unbaited control	0.60 (4)	0.60 (4)

Figure 13: Index to fox density at September 1997, northern jarrah forest, all treatments



very interesting

Figure 14: Index to fox density at September 1998, northern jarrah forest, all treatments



The 1997 derived index to density in all baited treatments was less than the unbaited control.

In 1998, the derived index indicated a reduced density in the 6 baitings per year treatment only. Although less than the unbaited control, the 1998 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. There was a period of six months, four months and two months between the most recent baiting event and derivation of the index to density for the 2, 4 and 6 baitings per year treatment respectively. This leaves a period of six, four and two months for immigration/dispersal to the 2, 4 and 6 baitings per year treatments respectively.

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 discrepancy between the 1997 and 1998 estimate of density for the 6 baitings per year treatment, and the lack of a detected fauna response from trapping data, indicate that the level of fox density reduction required to result in a sustained increase in native fauna abundance is still unclear.

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

4.6. Radio-telemetry monitoring of foxes.

Radio telemetry monitoring of foxes is not addressed and further work has been curtailed (see section 4.1).

4.7. Collection of site specific habitat and management data.

Collection of site specific data is scheduled for Spring 1999.

5. Project evaluation

Table 11 evaluates the project's progress in the major areas of activity against the milestones identified in the project proposal for 1997-98 and the project's intended final outcomes.

Table 11: Evaluation of progress

Major area of activity	Progress towards meeting milestones listed in 1997-98 proposal (Schedule 1 of Agreement)	Progress towards meeting the project's intended final outcome
Radio-telemetry monitoring of translocated woylies, *Bettongia penicillata*, and resident common brushtail possum, *Trichosurus vulpecula*	All milestones met for *Bettongia penicillata* monitoring. *T. vulpecula* monitoring reduced to two treatments (unbaited control and 6 baitings per year treatment)	Final analysis of woylie survivorship data scheduled for completion by 30 June 2000, as per identified milestones. Final analysis of *T. vulpecula* monitoring and survivorship scheduled for completion by 30 June 2000, as per identified milestones.
Twice yearly trapping at 43 trapping grids and 17 trapping transects	Number of grids increased to 55 to allow monitoring at long unburnt and unlogged sites within each treatment. Trapping increased to 4 times per year as per 1998-99 proposal. All milestones met	Final analysis scheduled by 30 June 2000
Twice yearly transect spotlighting	Milestones met for period to 30 June 1998. Spotlighting curtailed from 1 July 1998.	Progress curtailed
Index to fox density through the use of sandplots	Index has been derived annually. All milestones met	Final analysis scheduled post September 1999, subject to validation of technique. Validation of technique scheduled for September 1999.
Radio-telemetry monitoring of foxes	Progress curtailed	Progress curtailed
Collection of site specific habitat data	Scheduled for Spring 1999	Scheduled for Spring 1999

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Treatment Boundaries and Fauna Monitoring Sites within the Northern Jarrah Forest Fox Control and Research Program
OPERATION FOXGLOVE

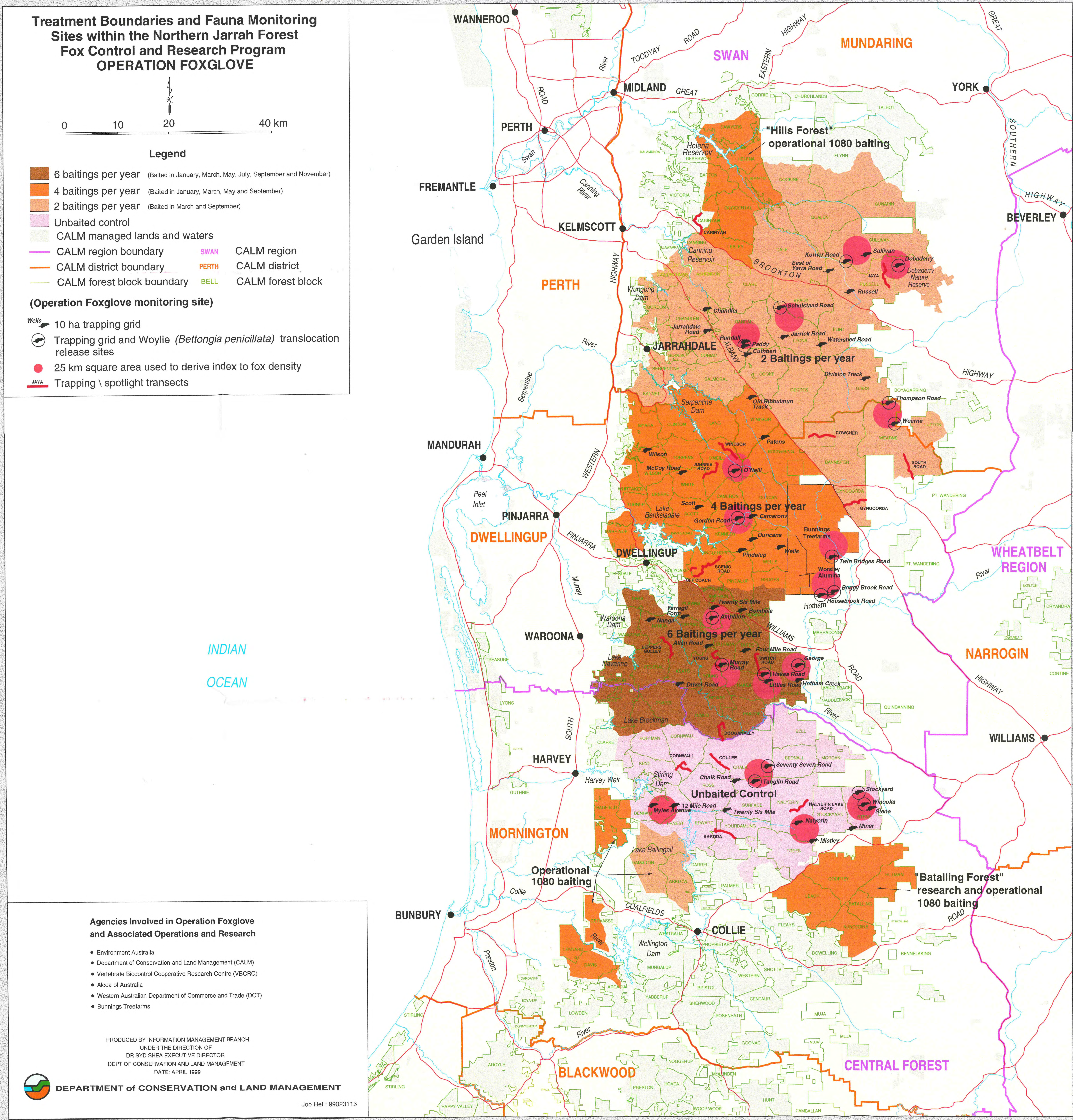
0 10 20 40 km

Legend

- 6 baitings per year (Baited in January, March, May, July, September and November)
- 4 baitings per year (Baited in January, March, May and September)
- 2 baitings per year (Baited in March and September)
- Unbaited control
- CALM managed lands and waters
- CALM region boundary — SWAN CALM region
- CALM district boundary — PERTH CALM district
- CALM forest block boundary — BELL CALM forest block

(Operation Foxglove monitoring site)

- Wells 10 ha trapping grid
- Trapping grid and Woylie *(Bettongia penicillata)* translocation release sites
- 25 km square area used to derive index to fox density
- JAYA Trapping \ spotlight transects



Agencies Involved in Operation Foxglove and Associated Operations and Research

- Environment Australia
- Department of Conservation and Land Management (CALM)
- Vertebrate Biocontrol Cooperative Research Centre (VBCRC)
- Alcoa of Australia
- Western Australian Department of Commerce and Trade (DCT)
- Bunnings Treefarms

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DEPARTMENT of CONSERVATION and LAND MANAGEMENT

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