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

Project Leader: Paul de Tores
Department of Conservation and Land Management
Wildlife Research Centre
P.O. Box 51, Wanneroo, Western Australia 6065

Precis

Research in Western Australia has demonstrated that numerous native mammal species have been advantaged through the use of sodium monofluoroacetate (or 1080) to control foxes.

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.

In accordance with the Commonwealth's Draft Threat Abatement Plan (TAP) for the fox, the northern jarrah forest study (Operation Foxglove) aims to reduce fox density sufficiently to result in increases in native fauna abundance over large areas of multiple use forest.

In doing so, the program will determine whether fox predation is the major limiting factor to native fauna abundance in the northern jarrah forest. The program is operating over approximately 550,000ha and is the largest fox control and research program undertaken within Australia.

The project is an integral part of the Vertebrate Bio-Control Co-operative Research Centre (VB CRC). 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.

The methodology employed to achieve the above goals will result in achieving specific management objectives including:

- determining efficient and cost effective 1080 baiting regimes for fox control over large tracts of conservation estate and multiple use forest;
- establishing additional populations of a threatened species (the woylie, *Bettongia penicillata*) within its former geographic range; and
- increasing the abundance of species listed as threatened, e.g. the chuditch, *Dasyurus geoffroii*.

The results to date indicate that an aerial baiting regime of 5 baits/km^2 delivered 4 times per year is sufficient to result in an increased level of survivorship of the translocated, indicator species, the woylie, at sites 5km or further from agricultural land. A higher baiting frequency (in excess of 6 baitings year) is required for forest areas within 5km of agricultural land.

If the longer term findings are consistent with these results, a baiting frequency of 6 times per year or more may be required at the forest interface with agricultural land. This is a more frequent baiting regime than currently used by managers and may require amending existing aerial baiting programs.

The same results have not been shown for resident species including the common brushtail possum, *Trichosurus vulpecula*, which is also considered an indicator species. Implications are that factors other than fox predation may be limiting common brushtail possum abundance and distribution.

The feral cat has also been shown to be a significant predator of translocated woylies. Data suggest that predation by feral cats may increase in the presence of fox control. This was previously not thought to be the case in forested areas of south west Western Australia and supports the assertion that cat control should be undertaken in conjunction with fox control.

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

Research Staff 1996-1997

Position	Person	Funding Source
Project Leader:	Paul de Tores	CALM
Contract Technical Officers/Consultants:	Kathryn Himbeck	VB CRC
	Cathy Lambert (1 July – 17 October 1996)	VB CRC
	Beth MacArthur (21 Oct. 1996 – 30 June 1997)	VB CRC
	Jim Cocking	Environment Australia
	Wendy Van Luyn (1 July 1996 – 12 Feb. 1997)	Environment Australia
	Michael Meffert (1 April – 30 June 1997)	CALM
Research Scientist:	Mike Yung (2.5%)	CALM
Senior Technical Officer:	Mike Dillon (5%)	CALM
Volunteers:	Suzanne Rosier	
	Birgit Brenninkmeijer	
	Dianne van Stipdonk	

1. Background

This report outlines progress for the period 1 July 1996 to 30 June 1997 for the project assessing native fauna response to various levels of fox density reduction through 1080 baiting in the northern jarrah forest of southwest Western Australia.

Proposed research for the period to June 2000 is outlined in the recently submitted application for continued funding.

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 shown 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.

Previous 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, N. Marlow and D. Algar unpublished and personal communication). The most efficient and cost effective baiting frequency for large areas is unknown.

The northern jarrah forest study (Operation Foxglove) aims to reduce fox density sufficiently to result in increases in native fauna abundance over large areas of multiple use forest. In doing so, the program will determine whether fox predation is the major limiting factor to native fauna abundance in the northern jarrah forest. The program is the largest fox control and research program undertaken within Australia and has compatible research and management objectives.

The project is an integral part of the Vertebrate Bio-Control 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.

The methodology employed to achieve the above goals will result in achieving specific management objectives including:

- determining efficient and cost effective 1080 baiting regimes for fox control over large tracts of conservation estate and multiple use forest;
- establishing additional populations of a threatened species (the woylie, *Bettongia penicillata*) within its former geographic range; and
- increasing the abundance of species listed as threatened, e.g. the chuditch, *Dasyurus geoffroii*.

2. Study Area, Design and Techniques

The study area (figure 1) is approximately 544,000ha. 1080 dried meat baits are aerially delivered at 5 baits/km^2. Baits are delivered from vehicle to areas at the interface with agricultural land. There are three different baiting frequencies and an unbaited control (figure 2). Treatment areas are:

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

2.1 Monitoring fauna response

Anecdotal accounts and results from previous *ad hoc* fauna trapping indicated that, prior to commencing the project, the suite of mammal species within the northern jarrah forest study area was at low density. A 4-5 year period post commencement of 1080 baiting has been required to detect a fauna response in other fox control programs in Western Australia. Therefore, if there is a fauna response in the northern jarrah forest, it could be expected to take 5 years or longer to be detected through trapping.

To detect a response within a shorter time frame, the woylie was selected as an indicator species and translocated to sites within all treatments. The woylie is considered a suitable indicator species for the 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), it has been successfully translocated from Dryandra Woodland to Boyagin Nature Reserve (a WA wheatbelt reserve within 20km of the northern jarrah forest study area) (Kinnear unpublished and personal communication), females reach sexual maturity at 6 months, can produce up to 3 young per year and the woylie's former geographic range included the northern jarrah forest study area (Christensen 1980; Christensen 1995).

The response (changes in abundance and differences in survivorship) of translocated woylies and the suite of small to medium size mammals is monitored in each treatment through:

- twice yearly trapping over 43 grids. Each grid is approximately 10ha. Twenty seven of these are integrated trapping grids with 25 wire cage traps, 15 Elliott traps and 15 pitfall traps. The remaining 16 (4 in each treatment) are comprised of wire cage and Elliott traps only. The trapping grid design is shown in figure 3;
- twice yearly trapping over 17 transects. Each transect is 5km;
- twice yearly spotlighting over 17 transects, as above;
- intensive radio-telemetry monitoring of translocated woylies; and
- radio telemetry monitoring of resident common brushtail possums.

Trapping is carried out in summer and winter, spotlighting in autumn and spring.

The frequency of trapping will increase to four times per year from July 1998. 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) is proposed for analysis of final trapping data. Use of these techniques will be subject to meeting assumptions of the models.

Kaplan-Meier survivorship functions and the non-parametric Log-Rank test modified for staggered entry (Pollock *et al.* 1989) are used to analyse survivorship of woylies and common brushtail possums. Home range is determined for the common brushtail possum, using the Harmonic Mean Measure 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 are 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 are accepted for use in home range analyses.

2.2. Fox density estimates

An index to fox density is derived annually (September–October) through the use of sandplotting. Sandplots are set within grids using the existing roading network. 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 and has 25 sandplots. Each sandplot is approximately 1m x 1m. Neighbouring sandplots are a minimum of 500m apart.

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.

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. 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 sandplots showing interference is interpreted as a second fox. The procedure is yet to be validated.

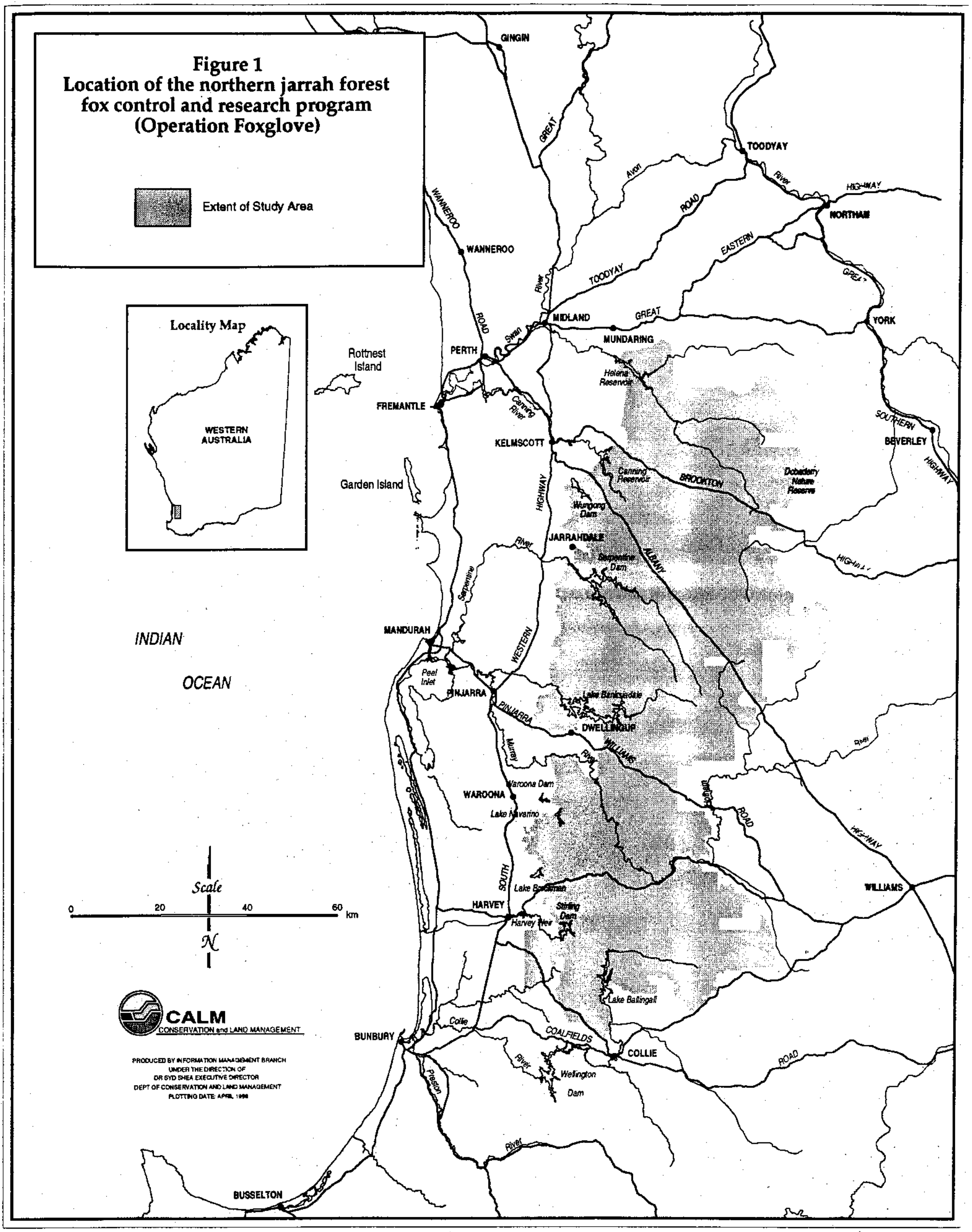


Figure 1
Location of the northern jarrah forest fox control and research program (Operation Foxglove)

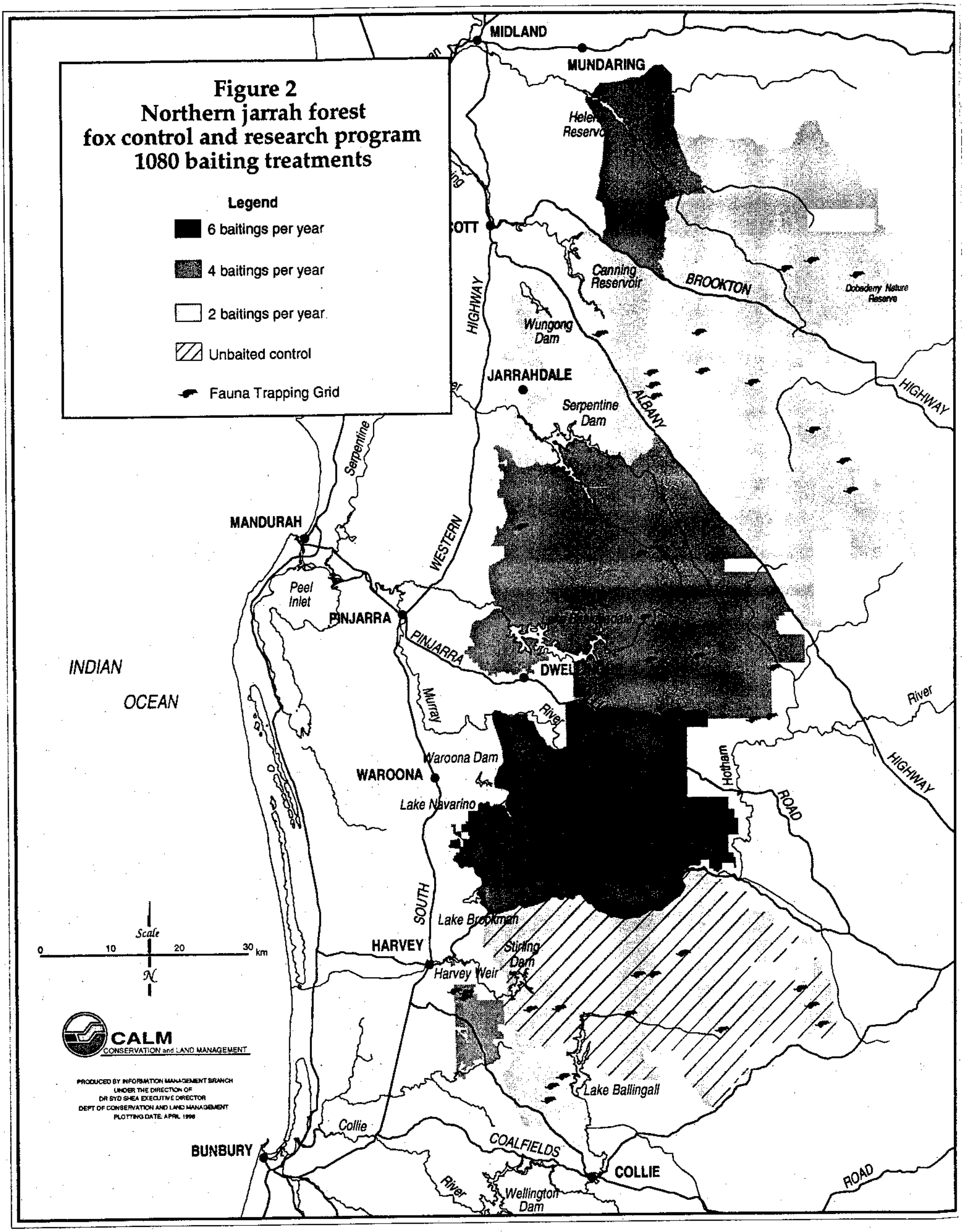


Figure 2
Northern jarrah forest fox control and research program 1080 baiting treatments

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.

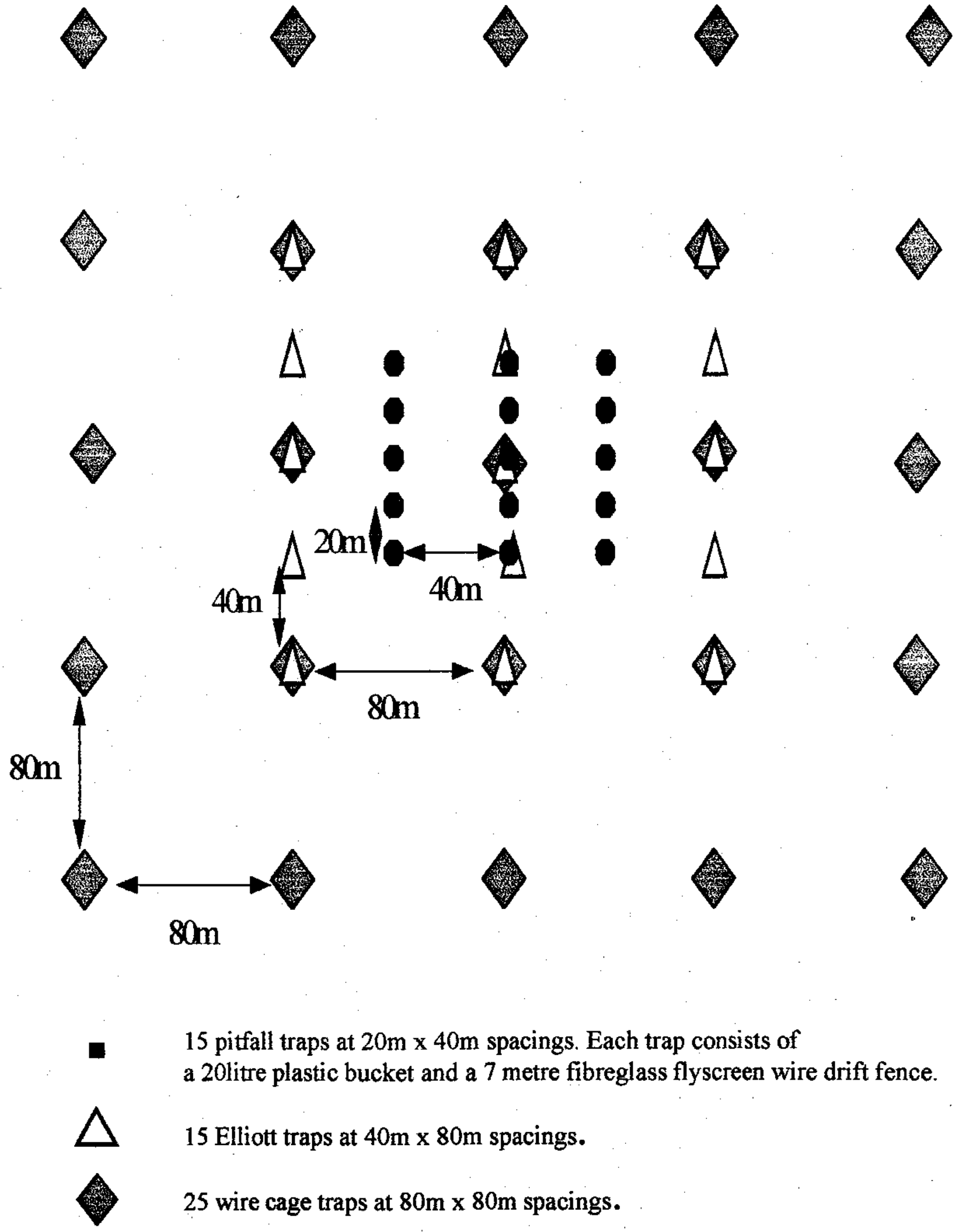


Table 1: History of 1080 baiting and baiting schedule to 30 June 2000; and History of woylie translocations to the northern jarrah forest.

Date	Baiting treatment (no. of baitings per year)			
	2 times	4 times	6 times	Unbaited control
July 1994		✓		
September 1994	✓	✓		
January 1995		✓ TP (perimeter)	✓ TP (perimeter)	
March 1995	✓	✓	✓	
May 1995		✓	✓	
July 1995			✓	
September 1995	✓ TR (Sept-Oct)	✓ TR (Sept-Oct)	✓	
November 1995			✓	
December 1995			TR (Nov-Dec)	
January 1996		✓	✓	TR
March 1996[1]	✓	✓	✓	
May 1996		✓	✓	
July 1996			✓	
September 1996	✓	✓	✓	
November 1996			✓	
January 1997		✓ TR	✓ TR	
February 1997				TR
March 1997	✓	✓	✓	
May 1997		✓	✓	
July 1997, '98, '99, 2000			X	
September 1997, '98, '99, 2000	X	X	X	
November 1997, '98, '99, 2000			X	
January 1998, '99, 2000		X	X	
March 1998, '99, 2000	X	X	X	
May 1998, '99, 2000		X	X	

✓: Baiting completed at 30 June 1997
X: Baiting scheduled
TP (perimeter): Pilot translocation of woylies to perimeter sites within 2 treatments
TR: Woylies translocated to sites within each treatment.
▬: Indicates when each treatment had received its requisite number of baitings for the preceding 12 months.
[1] The scheduled baiting for March 1996 baiting was undertaken in April 1996.

Progress on Specific Items

(Activities 1-7 as identified in the Contract Agreement)

1. *At an intensity of 5 baits per km² and frequency of aerial 1080 baiting at 2, 4 or 6 times per year, calculate the baiting regime necessary to allow native fauna to increase in abundance*

1080 baiting commenced in July 1994 for the 4 baitings per year treatment, September 1994 for the 2 baitings per year treatment and in January 1995 for the 6 baitings per year treatment.

The history of, and schedule for, 1080 baiting is shown in table 1. A summary of baiting history is shown in table 2.

Table 2: Summary of 1080 baiting within the northern jarrah forest at June 1996

Treatment (no. of baitings per year)	Date baiting commenced	Total number of baitings at 30 June 1997
2 times	September 1994	6
4 times	July 1994	13
6 times	January 1995	15

2. *Monitor resident native fauna twice yearly on established grids and transects through spotlighting and trapping.*

Selection of fauna monitoring sites and preliminary (pre baiting) fauna survey commenced in July 1993. Trapping and spotlighting has been undertaken twice yearly since 1993.

The data show no significant difference in fauna abundance between treatments. Trends in trapping data (shown as number of new captures, i.e. previously uncaught animals) are shown in figures 4-6 for woylie, chuditch and quenda or southern brown bandicoot (*Isoodon obesulus*) respectively.

Figure 4: new woylies trapped

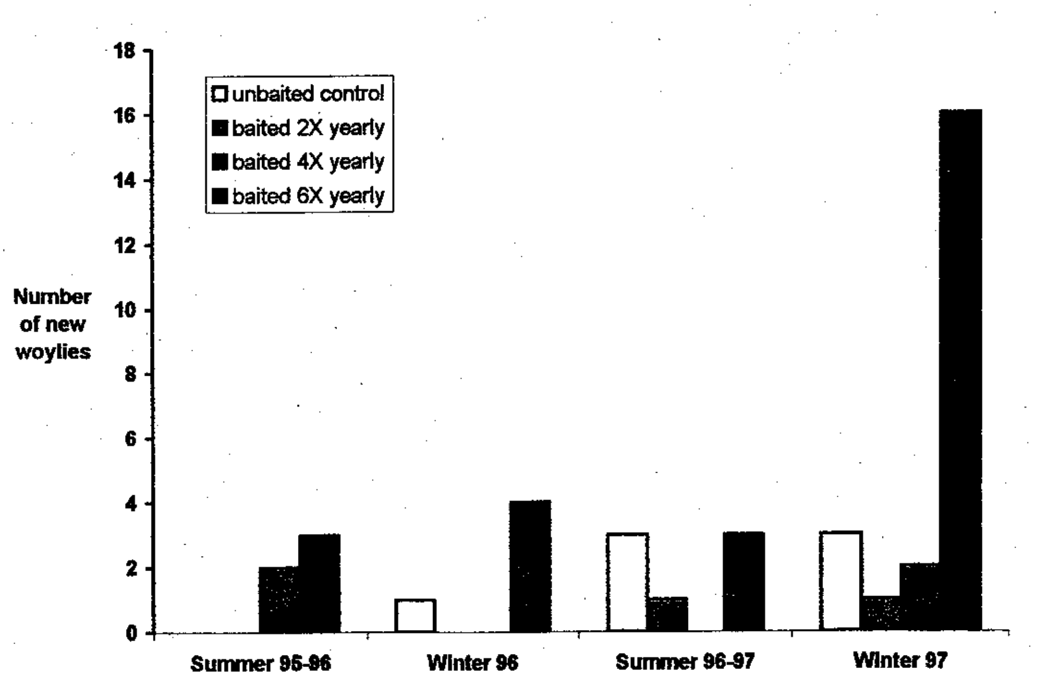


Figure 5: new chuditch trapped

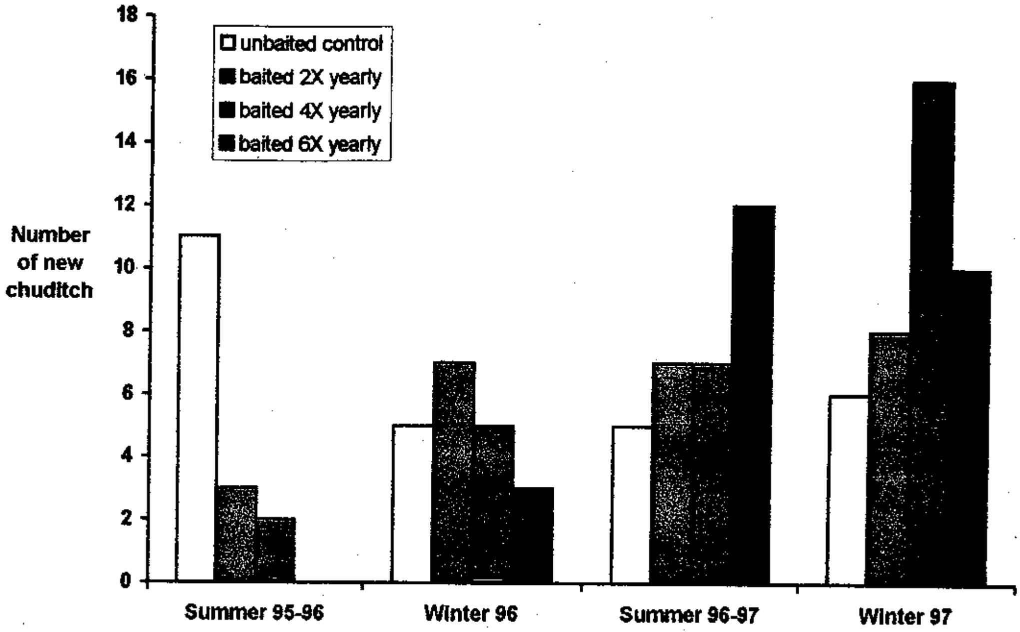
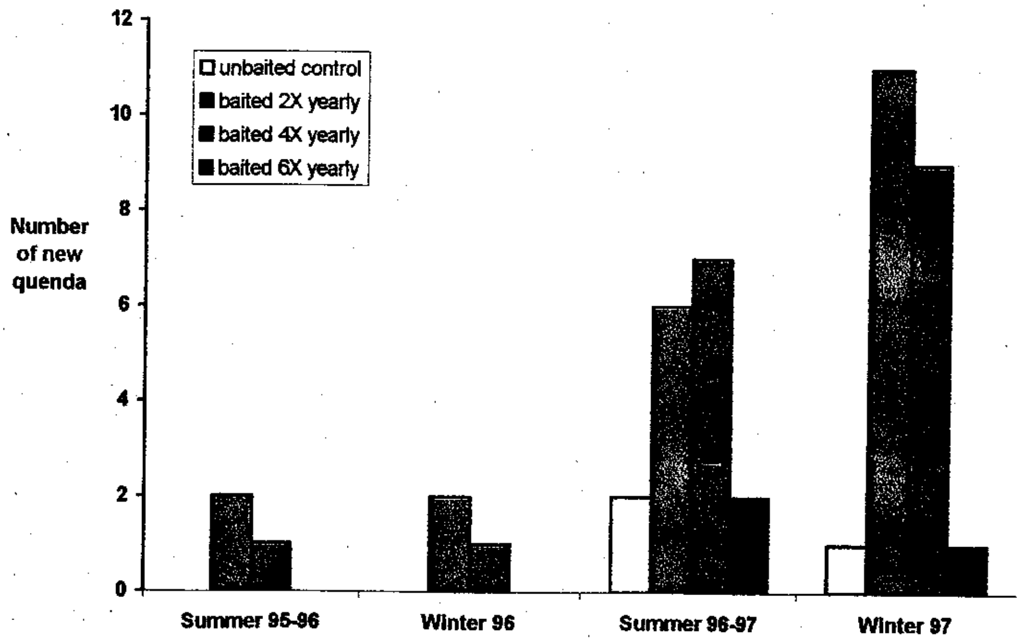


Figure 6: new quenda trapped



3. Monitor the survivorship of radio collared translocated and recruited woylies.

In January 1995, a pilot translocation was undertaken to 4 sites. Woylie survivorship was intensively monitored and indicated that survivorship was greater at distances of 5km or further from the interface with agricultural land. Subsequent translocations were carried out in September-October 1995 and October 1995-January 1996 to 18 sites over all treatments. Survivorship data showed a significantly higher level of survivorship ($p < 0.05$, Log-Rank test) at sites within the treatment with the highest baiting frequency (6 baitings per year) and 5km or further from agricultural land. The data also showed no difference in survivorship between treatments for sites less than 5km from agricultural land.

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

There have been subsequent translocations (January-February 1997) and intensive monitoring maintained. Results from these data are reported here.

Radio-collars were Biotrack, 2 stage whip aerial tags with movement sensitive mortality circuitry, with a 2½ hour period required to trigger mortality mode. Collars were specifically designed to fit woylies. Woylies were monitored for 24 days of each 28 day period.

Mortality tags and intensive monitoring allowed rapid detection of mortality events.

Data from intensive monitoring for the period January 1996 - June 1997 are shown below (figures 7–9) in the form of Kaplan-Meier survivorship functions modified for staggered entry (Pollock *et al.* 1989) for the 2, 4, 6 times per year baiting treatments and the unbaited control.

Figure 7 shows survivorship for all sites. Table 3 shows the level of survivorship at all sites at the end of the 78 week monitoring period. The 6 baitings per year treatment showed the highest level of survivorship, significantly different from the 2 and 4 baitings per year treatment and the unbaited control ($p<0.05$, Log-Rank test). For all sites combined, there was no other significant difference in survivorship.

Figure 8 shows survivorship for sites at 5km or further from agricultural land. Table 4 shows the level of survivorship at the end of the 78 week monitoring period. 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). For sites 5km or further from agricultural land, there was no other significant difference in survivorship.

Figure 9 shows survivorship for sites less than 5km from agricultural land. Table 5 shows the level of survivorship at the end of the 78 week monitoring period. 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). For sites less than 5km from agricultural land, there was no other significant difference in survivorship.

There have been 62 woylie deaths attributed to predation, of these, 22 deaths were attributed to fox and 14 to cat predation. Table 6 shows the number of deaths in each treatment and the predator considered responsible.

Figure 7: Kaplan-Meier Survivorship Functions for radio-collared woylies, all sites. For the Period 1 January 1996 - 30 June 1997

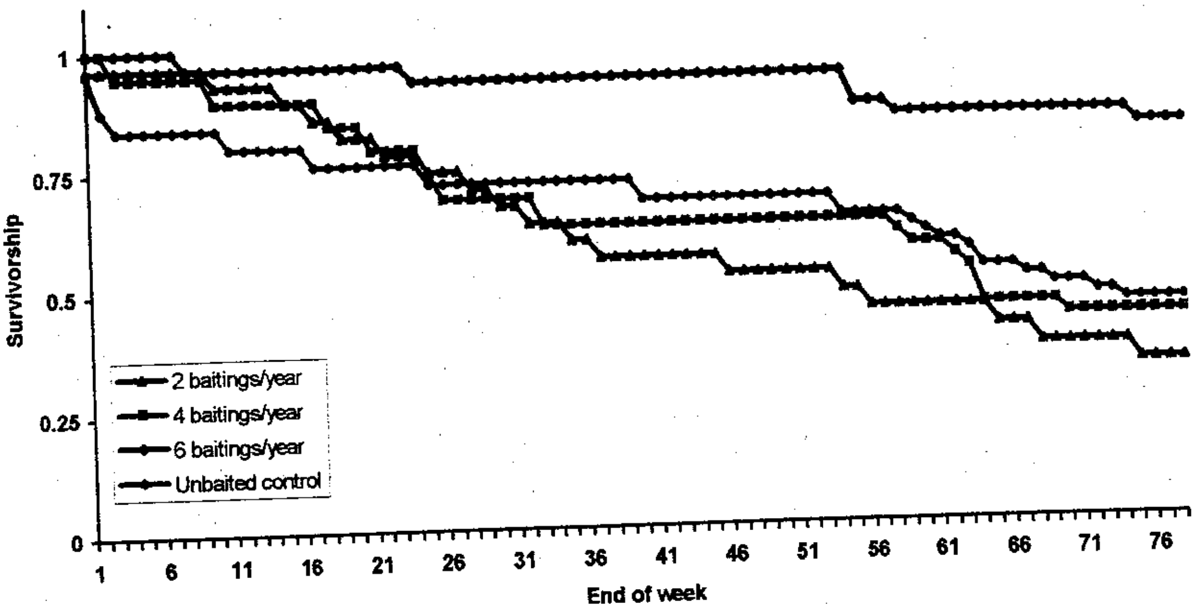


Table 3: Woylie survivorship for all sites, northern jarrah forest, at the end of the 78 week monitoring period, 1 January 1996 to 30 June 1997. Common superscript letters indicate a significant difference in survivorship ($p<0.05$, Log-Rank test)

Treatment	Survivorship (from Kaplan-Meier survivorship functions) at the end of the 26 week monitoring period 1 January to 30 June 1996.
2 baitings per year	0.32^{b}
4 baitings per year	0.42^{a}
6 baitings per year	0.82^{abc}
Unbaited control	0.45^{c}

Figure 8: Kaplan-Meier Survivorship Functions for radio-collared woylies, sites 5km or further from agricultural land. For the period 1 January 1996 - 30 June 1997.

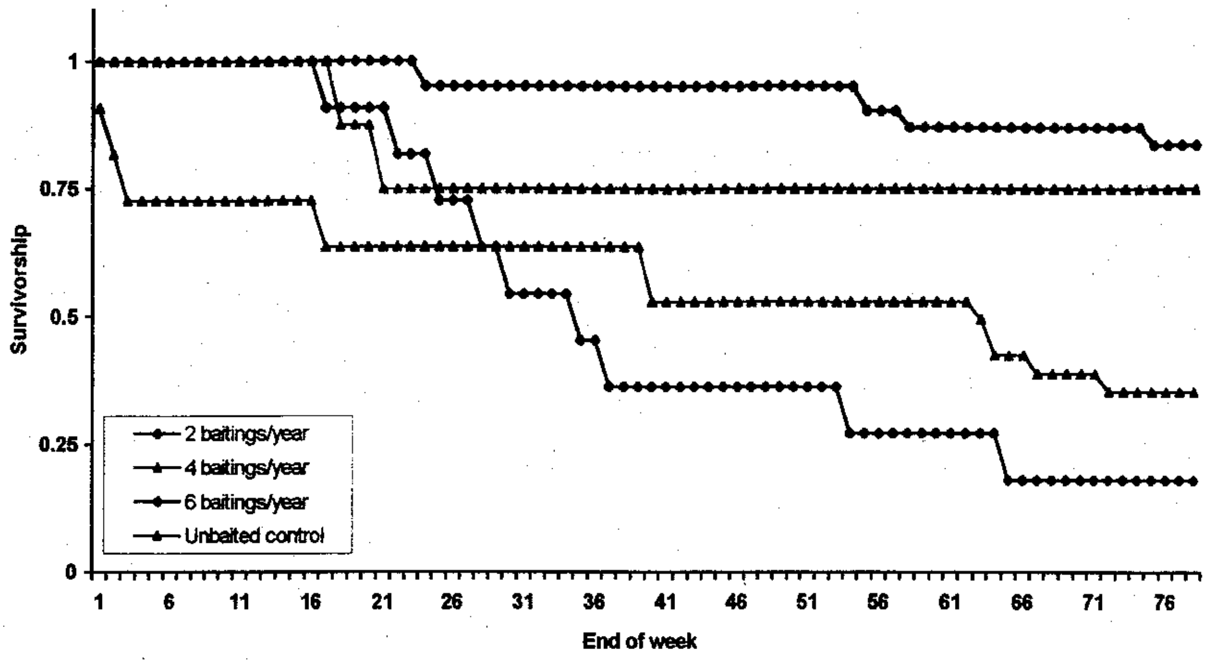


Table 4: Woylie survivorship for sites 5km or further from agricultural land, northern jarrah forest, at the end of the 78 week monitoring period, 1 January 1996 to 30 June 1997. Common superscript letters indicate a significant difference in survivorship ($p<0.05$, Log-Rank test)

Treatment	Survivorship (from Kaplan-Meier survivorship functions) at the end of the 26 week monitoring period 1 January to 30 June 1996.
2 baitings per year	0.18[ad]
4 baitings per year	0.75[cd]
6 baitings per year	0.84[ab]
Unbaited control	0.35[bc]

Figure 9: Kaplan-Meier Survivorship Functions for radio-collared woylies, perimeter sites. For the period 1 January 1996 - 30 June 1997.

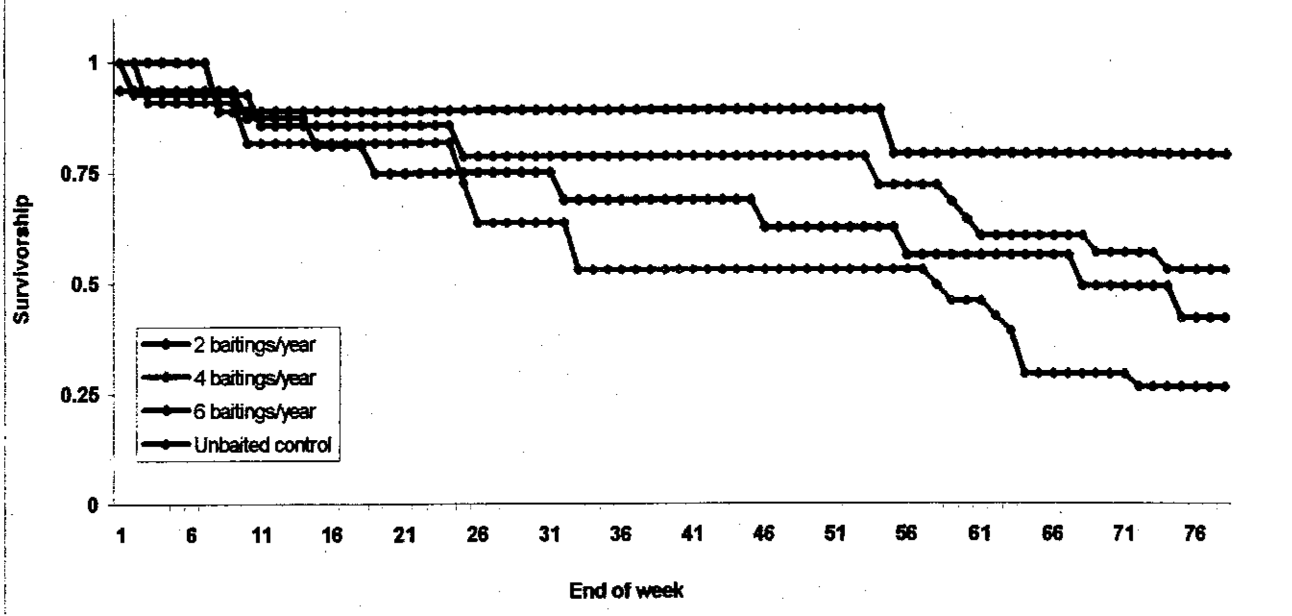


Table 5: **Woylie survivorship for sites less than 5km from agricultural land, northern jarrah forest, at the end of the 78 week monitoring period, 1 January 1996 to 30 June 1997. Common superscript letters indicate a significant difference in survivorship ($p<0.05$, Log-Rank test)**

Treatment	Survivorship (from Kaplan-Meier survivorship functions) at the end of the 26 week monitoring period 1 January to 30 June 1996.
2 baitings per year	0.42
4 baitings per year	0.26[a]
6 baitings per year	0.79[a]
Unbaited control	0.53

Table 6: Woylie deaths attributed to predation and predator considered responsible.

Treatment	Predator responsible					Total
	Fox	Cat	Fox/Cat?[1]	Unknown[2]	Other (raptor, python)	
2 baitings per year	3	9	0	4	1	17
4 baitings per year	8	3	4	3	1	19
6 baitings per year	4	2	0	3	0	9
Unbaited control	7	0	2	7	1	17
Total	22	14	6	17	3	62

(1) 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.

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

4. Monitor the survivorship, habitat use and dispersal patterns of the common brushtail possum.

A total of 44 common brushtail possums has been trapped in the period 30 April 1994 to 30 June 1997, as per table 7. Of these, 23 have been radio collared and survivorship monitored. There has been no detectable difference in survivorship between treatments.

Preliminary data only has been collected on home range and habitat use. Home range data for 8 possums are shown in table 8.

Table 7: Number of common brushtail possums trapped over all treatments, 30 April 1994 – 30 June 1997

Treatment	Number of possums trapped
2 baitings per year	21
4 baitings per year	11
6 baitings per year	1
Unbaited control	11
Total	44

Table 8: Estimated home range for common brushtail possums from 2 and 4 baitings per year treatments. Harmonic Mean Measure (HMM) and Minimum Convex Polygon (MCP), 95% isopleths.

Treatment and Animal ID	Number of fixes used to estimate home range	Home range estimates (ha.)	
		HMM	MCP
2 baitings per year			
M2004	32	32.67	20.03
M2006	34	245.08	225.18
M2008	30	14.37	64.47
4 baitings per year			
F4005	16	5.16	9.06
F4006	14	4.00	10.14
M4003	24	55.32	67.71
M4006	26	18.90	64.14
M4007	16	2.65	8.27

Common brushtail possums have been recorded using tree hollows in jarrah, *Eucalyptus marginata*, wandoo, *E. wandoo*, and marri, *E. calophylla*. For the period 19 March to 6 June 1997 there were 183 recorded uses of 76 individual tree hollows. Table 9 shows the number of recorded hollows for each species.

Table 9: Recorded use of tree hollows for the period 19 March to 6 June 1997.

Tree Species	Number of tree hollows recorded	Total number of recorded use of tree hollows
Jarrah, *Eucalyptus marginata*	38	89
Wandoo, *E. wandoo*	25	67
Marri, *E. calophylla*	13	27

5. ***Derive an index for fox density through sand plots and telemetry data.***

Fox density estimates derived from sandplotting are shown in table 10.

Table 10: Northern jarrah forest estimates of fox density from sandplots. September - October 1996

Treatment	Estimated number of foxes/25km^2 sandplot grid	
	Agricultural/forest interface	Core (5km or further from agricultural/forest interface)
Unbaited control	2	0.67
2 baitings/year	1.5	0.67
4 baitings/year	1.0	0.5
6 baitings/year	1.0	0.33

6. ***Trap and monitor mortality of trapped foxes and feral cats.***
7. ***Undertake a pilot study to determine the feasibility of using conventional movement sensitive mortality transmitters and satellite telemetry for monitoring fox and cat survivorship within the northern jarrah forest.***

These items are not addressed and have been deferred to the 1997-98 program. Work commenced on these in May 1998 and will be reported in the 1998-99 project report(s). See covering letter with this report

Discussion

Baiting regimes and woylie survivorship

Deriving the appropriate 1080 baiting regime for large tracts of multiple use forest will be dependant upon determining whether there is a fauna response to fox density reduction through 1080 baiting. Trapping data show no significant increase in abundance although there are trends of an increase in captures of new (previously untrapped) woylies, chuditch and quenda (figures 4 - 6).

Tables 1 and 2 show the history of baiting and total number of baitings for each treatment at 30 June 1997. Table 11 below, shows the anticipated number of baitings for each year to 30 June 2000.

Table 11: Anticipated cumulative number of 1080 baitings for each baited treatment within the northern jarrah forest to 30 June 2000.

Treatment	Cumulative number of baitings at:			
	30 June 1997	30 June 1998	30 June 1999	30 June 2000
2 times per year baiting	6	8	10	12
4 times per year baiting	13	17	21	25
6 times per year baiting	15	21	27	33

Given the short time since commencement of baiting, the results are consistent with other fox control programs where fauna abundance was low prior to commencement of 1080 baiting. An increase in abundance of the woylie was detected 5 years post commencement of monthly baiting at Tutanning Nature Reserve and an increase in abundance of the common brushtail possum was detected 5 years post commencement of monthly baiting at Boyagin Nature Reserve (Kinnear unpublished). Similarly, rock wallaby populations at several Western Australian wheatbelt sites showed an increase in abundance 4 years post commencement of 1080 baiting (Kinnear *et al.* 1988).

Although a fauna response cannot be assumed, the differences in survivorship shown by the chosen indicator species, the woylie, is evidence of a response to fox density reduction (figures 7 and 8; tables 3 and 4). The data showed that at 4 (and 6) baitings per year and at sites 5km or further from agricultural land, there was a significantly higher level of survivorship of the monitored woylie population (figure 8 and table 4). The implications are that the level of fox density reduction achieved by 4 baitings per year is sufficient to result in a fauna response. These data contrast with earlier reports where 6 baitings per year was required to result in a significantly higher level of survivorship in the central core of the jarrah forest (see 1995-96 report). The difference between the June 1996 result and the June 1997 result may be a function of the time since commencement of baiting.

Figure 9 and table 5 indicate that 6 baitings per year does not result in an increased level of woylie survivorship at sites less than 5km from agricultural land. These data are consistent with the 1996 results and imply that in excess of 6 baitings per year is required to achieve a fauna response at the forest/agricultural land interface.

The results show significantly higher levels of predation of woylies at the interface of forest and agricultural land. If the longer term findings are consistent with the results to date, a baiting frequency of 6 times per year or more may be required at this interface. This is a more frequent baiting regime than currently used by managers and may require amending existing aerial baiting programs.

Attributing predation events

Table 6 lists the predator believed responsible for the 62 woylie deaths attributed to predation. Attributing predation to a particular predator is subjective. Table 12 below, lists the diagnostic features used to differentiate between predation events attributed to cats and those attributed to foxes.

Table 12: **Diagnostic features used to differentiate between cat and fox kills of the brush-tailed bettong, *Bettongia penicillata*, at the northern jarrah forest research sites.**

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. 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.

The data (table 6) show comparable numbers of predation events attributed to cats and foxes in all the baited treatments and no predation events attributed to cats in the unbaited control. The implication is that predation by cats may increase in the presence of fox control. This was previously not thought to be the case in forested areas of south west Western Australia. If the longer term findings are consistent with the results to date, they will support the assertion that cat control measures should be incorporated when undertaking fox baiting.

Brushtail possum survivorship

Survivorship data for the common brushtail possum are not consistent with survivorship data for the woylie. There was no difference, between treatments, in survivorship of common brushtail possums, however this may be a function of the small sample size. Only 23 possums have been radio-collared since 1994, only one of these is from the 6 baitings per year treatment. Similarly, a "not significant" result when comparing survivorship may reflect survivorship of adults, not survivorship of the possum population. The majority of radio-collared possums were adults and unpublished data from the VB CRC Burrendong Dam Study, NSW has indicated that juvenile and sub-adult possums are more susceptible to predation than adults (A. Newsome pers. com.). Similarly, Kerle (1984) noted most population studies of the common brushtail possum showed that adult possums persisted, whereas dispersing young and individuals who had not successfully established a home range were more susceptible to predation by dingoes.

The home range estimates (Harmonic Mean Measure, HMM) for the northern jarrah forest brushtail possums are larger than the only other reported home range estimates in Western Australia (Sampson 1971; Inions 1985). Sampson (1971) used a minimum area estimate (presumably comparable to the minimum convex polygon method) and Inions (1985) reported a "utilisation area". In addition to the HMM, Minimum Convex Polygon (MCP) estimates are reported (table 8) for the northern jarrah forest possums to allow comparison with Sampson (1971). The MCP estimates are also larger than those reported by Sampson (1971) and the utilisation areas reported by Inions (1985).

The low density and larger home range estimates for the northern jarrah forest possums are consistent with the trend shown in the data reported by Kerle (1984) of increasing home range size with decreasing abundance. However, the northern jarrah forest home range data should be interpreted cautiously, as the majority of locations (fixes) were diurnal and may not accurately represent true foraging areas. The aberrant appearing home range estimate for possum M2006 reflects his pattern of use of 3 discrete areas of activity. Two of these were widely separated from each other, with one accounting for 35% and the other 50% of the total number of locations.

The patchy distribution and lack of a detectable response of common brushtail possums to fox control in the northern jarrah forest also support the assertion that factors other than predation by foxes influence abundance and distribution. Kerle *et al.* (1992) outlined a model, based on Morton's (1990) model, to explain the decline in distribution and abundance of the common brushtail possum in arid Australia. Implicit in this model is that no one single factor is responsible for the decline. The effect of predation was proposed to be greatest when other factors, especially long term drought and habitat alteration, were operating in concert and brushtail possum populations had contracted to refuge sites. Kerle *et al.* (1992) believed that dingoes in particular can impose predation pressure on brushtail possums when populations were depleted. Cattling *et al.* (cited by Kerle 1984) claimed that the dingo was the only predator known to consistently consume brushtail possums, however, our records from the northern jarrah forest indicate the fox and chuditch are predators of the common brushtail possum. Similarly, several studies have reported the presence of brushtail possum remains in fox scats (Coman 1973; Rose *et al.* 1993). Jones and Coman (1981) also recorded remains of the common brushtail possum in the stomach and intestines of cats sampled from two sites in Victoria and one in NSW.

There is circumstantial evidence from studies in Western Australia implicating the fox as a predator of the common brushtail possum. Albeit without controls or replication, the common brushtail possum has been shown to increase in abundance in the presence of fox control at Boyagin Nature Reserve (Kinnear unpublished and pers. com.) and at Leschenault Peninsula Conservation Park (de Tores, Rosier and Paine unpublished).

Fox densities

An index to fox density has been derived for all treatments in September - October each year for three consecutive years.

The procedure uses a sandplotting technique, whereby the index is derived from the frequency of interference (detected by the presence of spoor) at individual sand plots. The technique has the potential to overestimate abundance as a result of learned behaviour, therefore violating the assumption of independence of each plot. Irrespective of this, the data for 1994 and 1995 showed no relationship between the index to fox density and baiting treatment. However, this may have been a function of the limited number of baitings received by each treatment (table 13).

In 1996 the technique was modified and the index to density was derived from the number of runs of consecutive sandplots showing fox activity (see section 2.2). Table 10 shows the derived index to density for all treatments at September/October 1996.

The 1996 data were the first to show a relationship between the treatments and the derived index to fox density.

The data should still be interpreted cautiously given the limited number of baitings each treatment had received when the fox density estimates were derived (table 13).

Table 13: Total number of baitings received by each treatment at each year, when fox density estimates were derived.

	Total number of baitings at:		
Treatment	**September 1994**	**September 1995**	**September 1996**
2 times per year baiting	1	3	5
4 times per year baiting	2	6	10
6 times per year baiting	0	5	11
Unbaited control	0	0	0

Subject to continued funding, the technique will be validated and the estimate/derived index to fox abundance will be supplemented by data from trapping and radio-telemetry study of foxes.

Proposed Program July 1997 – June 2000

The Commonwealth's Threat Abatement Plan (TAP) for the fox recognised that Commonwealth funding for fox control should be determined on the basis of meeting the following criteria:

1. where fox predation presents a threat to continued survival of endangered or threatened species;
2. where there is a good potential for recovery of native populations under fox control; and
3. where large scale fox control would be efficient and effective.

The northern jarrah forest project meets all criteria.

An application for renewed funding was submitted to Environment Australia for the period to 30 June 2000. The proposal sought to continue 1080 baiting under the current regimes. Monitoring resident native fauna abundance was proposed to continue through twice yearly spotlighting and twice yearly trapping (increasing to 4 times per year from July 1998).

Monitoring of radio-collared translocated and recruited woylies will continue. Collection of data will concentrate on survivorship (mortality) and analysis will continue to be through Kaplan-Meier Survivorship Functions and Log Rank Test.

The sample size of radio collared woylies will be increased within each treatment through collaring of previously released uncollared animals as they are re-trapped, collaring of recruits to the population and supplementary translocation(s) if required.

The radio-telemetry monitoring allows assessment of differences in woylie survivorship between treatments and differences in survivorship within treatments, specifically differences in survivorship between core sites and sites at the interface with agricultural land. However, interpreting survivorship as a function of frequency of 1080 baiting relies on the premise that fox predation is limiting woylie survivorship. As this cannot be assumed, the program proposes to assess the importance of site specific habitat and management variables (e.g. floristics, structure, fire history etc.).

Survivorship of common brushtail possums will also continue to be monitored and the sample size will be increased. Monitoring will place emphasis on survivorship of juveniles and sub-adults.

Data have indicated that predation by cats may increase in the presence of fox control. This was previously not thought to be the case in forested areas of south west Western Australia. Therefore, it is proposed to assess the importance of the role of other predators, including feral cats.

Sand plots will continue to be used to derive an index to fox density. The results to date have indicated a relationship between frequency of 1080 baiting and fox density. The technique is yet to be validated.

A pilot study involving trapping for foxes and cats, using Victor Softcatch and conventional wire cage (for cats) traps, was proposed to commence in July 1996. This has now been deferred to July 1998. Standard trapping transects will be established within the 6 baitings per year treatment and the unbaited control. All trapped foxes and cats will be radio-collared using movement sensitive mortality transmitters.

A pilot study (also deferred to July 1998) will be undertaken to assess the feasibility of conventional movement sensitive mortality transmitters and satellite telemetry for monitoring fox and cat survivorship.

Subject to the outcome of the trial, data will be collected on survivorship home range and dispersal patterns. Particular emphasis will be placed on determining whether individuals survive successive 1080 baiting episodes, determining home range within the jarrah forest and whether individuals are moving between baiting treatments and/or between forested and agricultural areas.

Also subject to the outcome of the satellite telemetry trial, fox density estimates derived through sandplotting will be supplemented by trapping and radio telemetry/satellite telemetry data.

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1996-1997 Report to

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ISP#05
Control and Ecology of the Red Fox in Western Australia
Prey Response to 1080 Baiting Over Large Areas.

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(for the period 1 July 1996 – 30 June 1997)

Project Leader: Paul de Tores

Department of Conservation and Land Management
CALMScience Division
Wildlife Research Centre
P.O. Box 51 Wanneroo
Western Australia 6065