3. The Efficacy of Replacement-baiting for the Control of Wild Dogs

3.1 Introduction

In accessible terrain, ground baiting is preferred by Wild Dog Control Association members to aerial-baiting for the control of wild dogs. However, the efficacy of existing ground baiting programs, which use the single placement of meat baits containing 1080 poison (sodium fluoroacetate), has been questioned. After a ground-based baiting campaign using small meat baits containing 20 mg of 1080 in central Australia, Best *et al.* (1974) achieved a 69% reduction in dingo sign. Their program was assessed by counting dingo tracks around waterholes before and after baiting. The baited site was compared with an unbaited site that simultaneously exhibited a small (3%) reduction in dingo tracks. McIlroy *et al.* (1986a), using three placements of meat baits, were able to kill only 22% of a small sample (n=9) of radio-collared wild dogs. A study by Bird (1994) in the arid zone of South Australia, used a single placement of 430 baits to achieve a reduction of 10-13% of 300- 400 dingoes that were watering at a single bore.

As stated in Chapter 1, spotted-tailed quolls are the non-target native animals most likely to be at risk from 1080 meat baits. Foxes were also considered to be non-target animals by McIlroy *et al.* (1986a) and foxes removed approximately 48% of baits laid for wild dogs in the first baiting of their study. Red foxes are often present in forested locations that are baited to reduce wild dog populations (e.g. McIlroy *et al.* 1986a; Smith *et al.* 1992; this study).

In a study of red fox management, Thompson and Fleming (1994) suggested that "replacement-baiting" (the daily replacement of baits which had been removed by target animals until few or no baits are taken) would maximise the number of foxes killed by ground baiting programs. This procedure has not been attempted for wild dogs. The replacement-baiting protocol differed from that usually employed by land managers in that the number of baits that were available was held constant by the daily replacement of removed baits. The usual practice is to place a given number of baits in the field and leave them for several days before either collecting and destroying the remaining baits or leaving the remaining baits to decompose in the field.

The aim of the experiment reported in this chapter was to determine the efficacy, as measured by percentage reduction in population abundance indices, of replacement-baiting for wild dog management. The results of this experiment are compared with the efficacy of baitings reported in previous studies. Estimates of the size of wild dog populations are discussed. The impact of co-occurring populations of foxes on baiting programs for wild dogs and the risk posed to non-target animals by replacement-baiting are also discussed.

3.2 Methods

3.2.1 General

The study was conducted over six weeks in January and February 1993 at Sites 1, 2 and 3 (Fig. 2.1). Wild dogs, foxes and spotted-tailed quolls were known to be present (Smith *et al.* 1992; Catling and Burt 1995; Fleming and J. Thompson unpublished data), but their relative abundance at each site was not known prior to the study. Manufactured baits were used (see Appendix I), each weighing 35g and containing a nominal loading of 5mg of 1080 poison, in a small polymer-encapsulated tablet. These baits and fresh meat have been shown to be acceptable to wild canids (Fleming 1993; Appendix I). The bait medium has been shown to be suitable for both ground and aerial baiting (Fleming and Thompson 1993). The baits were dyed green to reduce their attractiveness to non-target animals, particularly birds (Rathore 1985; McIlroy *et al.* 1986b).

3.2.2 Abundance Indices Before and After Replacement-Baiting

An index of abundance was calculated simultaneously for each species and each site before and after the treatment sites were baited. To establish indices of abundance at each site, between 75 and 100 bait-stations were constructed on the verges of forestry roads and tracks on alternate sides and at 250m intervals. A bait-station consisted of a 1m x 1m square of raked sand in the centre of which a bait was buried 1-5cm under the surface. Baits were buried to avoid their removal by birds but without reducing their attractiveness to wild canids (Allen *et al.* 1989). Small pieces (≈ 25g) of dried, unpoisoned kangaroo meat were used as baits. The same bait-stations were used for the before-baiting and after-baiting indices and were also used as poisoned-bait sites during

treatment (methods as per Thompson and Fleming 1994). I attempted to use this methodology to index the quoll populations at each site but the methods were unsuitable because of the low interaction between quolls and bait-stations.

Bait-stations were inspected at approximately the same time daily for nine to 14 days and baits were replaced if they had been removed. The species of animal visiting a bait-station was determined from footprints and other signs left on the sand. If an animal visited a bait-station during the before- and after-baiting index periods, the visit was included in the index regardless of whether the bait was taken. Where rain, livestock or vehicles had obliterated a bait-station, the station was re-raked and omitted from that day's analyses.

The protocol for obtaining the after-baiting abundance indices was identical to that of the before-baiting estimates. Collection of after-baiting indices began three days after baiting with 1080-impregnated baits was completed.

The indices of abundance were compared using Student's *t*-analyses, after first using analysis of variance (ANOVA) to determine whether before-baiting and after-baiting population variances were homogeneous (Steele and Torrie 1960).

3.2.3 Replacement-Baiting Program

The baiting treatment was administered three days after the before-baiting indices were completed. Sites 1 and 3 were poisoned with green, manufactured baits each weighing 35g and containing a nominal loading of 5mg of 1080 poison, in a small polymer-encapsulated tablet. Testing of manufactured alternative baits (Appendix I) showed that they were as suitable as meat baits for poisoning wild dogs, but were of reduced palatability to non-target species. A manufactured bait was buried 1-5 cm deep in the centre of each bait-station. Bait-stations were checked daily (for 10 days at Site 1 and 14 days at Site 3) and a new bait was placed at a station if the previous bait had been removed.

3.2.4 Estimates of Population Size

For treatments involving the removal of a known number of wild dogs and foxes, indices of density taken before and after a population is reduced can be used to estimate population size (Caughley 1980). An estimate of wild dog numbers at each site was made using the method of Thompson and Fleming (1994).

The number of dogs and foxes that were killed was estimated using the following assumptions:

Within the study sites the exact location of poisoned baits was mapped. All baits taken in sequence within a distinct topographical area in one day were assumed to have been taken by one animal (Thompson and Fleming 1994). On some occasions it was obvious from the footprints that more than one dog had visited a string of stations from which baits were removed. However, I conservatively assumed that only one of the animals had consumed all the baits in the string.

Given the 1080 dose in each bait (≈ 5.0 mg) and the indication of McIlroy and King (1990) and McIlroy (1981) that 2.5 mg is sufficient to kill any wild dog or fox, I assumed that any canid that ate one bait would have died.

Caching of baits (i.e. burying for subsequent recovery) was assumed not to affect the consumption of a bait by an individual animal. Macdonald *et al.* (1994) reported the caching of surplus eggs by red foxes observed in a loggerhead turtle hatchery in Turkey. However, some eggs were always eaten before any were cached. Moreover, 79% of re-excavated caches were completely consumed. Dogs will also bury surplus food items, as do wolves and coyotes (Harrington 1981). Burying baits does not reduce or increase bait-uptake by wild dogs (Allen *et al.* 1989). The presentation of baits in my study simulated caches made by canids and I assumed that the majority of baits discovered by foxes and wild dogs would have been eaten with a small proportion re-cached. The important corollary was that at least one bait would be eaten by the target animal before caching commenced.

The time taken between consumption of a bait and death is less than 14 hours for foxes (Thompson and Fleming 1994) and less than 9 hours for dogs (Tourtellotte and Coon 1951). Bird (1994) observed symptoms of 1080 poisoning in dingoes within 2.5 hr of laying baits and deaths within 5 hr. Consequently, a canid that had eaten a bait on one day would be unlikely to have survived to remove a bait on the following day. Therefore, poisoned baits removed on subsequent days were assumed to have been taken by different individuals.

The index-manipulation-index calculation (Caughley 1980) was used to estimate the number of dogs and foxes using the roads at the treatment sites i.e.;

$$N_1 = [I_1 / (I_1 - I_2)] * C,$$

where N_1= the population size before treatment, C= the number of animals removed, and I_1 and I_2 are the indices derived before and after the treatment.

The population abundance at Site 2 was not manipulated so that it was impossible to use index-manipulation-index to calculate the population size. However, the length of transects and vegetation were equivalent at Sites 2 and 3 so the abundance estimate for Site 3 was used to calculate that of Site 2 in the following manner. On Site 2, the population abundance was estimated by converting the initial population estimate for Site 3 to a number of animals per density-index unit and multiplying by the mean initial index of density for Site 2.

Having estimated the minimum number of animals killed each day, it should have been possible to estimate the size of the wild dog and fox populations before the baiting by using Leslie's method (Leslie and Davis 1939) and De Lury's method (De Lury 1947). Respectively, these methods rely on regressions of catch per unit effort plotted against previous cumulative catch and logged catch per unit effort plotted against effort expended prior to each catching occasion to estimate the initial size of a population. However, the estimated numbers of wild dogs and foxes that were killed each day by the baiting were

too variable so that the r^2 values of the regressions were below 0.5, thus precluding the use of either method.

The estimates of abundance reflect the number of wild dogs and foxes using the roads in each transect and therefore may underestimate the total populations of wild dogs and foxes at each site. Because the areas that were sampled were not delineated, the densities of each population of canids could not be calculated. Therefore the estimates were conservative estimates of the maximum number of wild dogs and foxes that could be found within the study sites during the study. This is because the estimates include animals with only a proportion of their home range within the study areas. The home range sizes of wild dogs and foxes in the area were unknown.

The cumulative number of wild canids that were killed at each treatment site was regressed against days using a generalised linear model (GLM) in GENSTAT5. These data were expected to describe asymptotic curves of the form;

$$y = a + br^x.$$

To test for differences between the populations at Sites 1 and 3, the curves were contrasted using accumulated ANOVA in GENSTAT5.

3.3 Results

3.3.1 Abundance Indices and the Efficacy of Baiting

Before-baiting indices (Table 3.1) were derived from frequencies of visitation over 720 bait-nights (1 bait-nigh = the exposure of one bait-station over one night) at Site 1, 951 bait-nights at Site 2 and 1,020 bait-nights at Site 3. The after-baiting indices were determined from 608 bait-nights at Site 1, 839 at Site 2 and 980 at Site 3. The differences in the number of bait-nights at each site reflected the numbers of bait-nights that were omitted from analysis because of obliteration by cattle, rain or vehicles.

Sites 1 and 3 showed similar, significant reductions in wild dog population abundance (mean= 76.1%, S. E.= 2.1). The nil-treatment site showed no significant changes in wild dog abundance indices over the period of the experiment. Red fox

populations at the treatment sites were reduced by 90.8% (S. E.= 4.0). The index of fox abundance at Site 2 also decreased but both the before- and after-indices were very low (Table 3.1).

Table 3.1. Indices of the abundance of wild dogs and foxes before and after a replacement-baiting program using 1080 baits. Sites 1 and 3 were treatment sites and Site 2 was un-treated. (S. E.). *ΔD*= the proportional change in mean density index.

Species	Site	Before-baiting index	After-baiting index	*ΔD* (%)	*t*	*P*	d.f.
Wild dog	1	0.114 (0.023)	0.025 (0.004)	-78.2	3.862	<0.001	14
	2	0.586 (0.048)	0.686 (0.118)	+17.2	-0.827	0.212	12
	3	0.367 (0.079)	0.095 (0.013)	-74.0	3.403	0.003	11
Red fox	1	0.285 (0.040)	0.015 (0.006)	-94.7	6.611	<0.001	8
	2	0.035 (0.010)	0.011 (0.005)	-68.6	2.064	0.034	10
	3	0.096 (0.026)	0.013 (0.006)	-86.8	3.014	0.006	11

3.3.2 Estimates of Population Size

The initial number of wild dogs at Site 1 was estimated at 17 animals and 22 dogs at Site 3. After baiting, an estimated three wild dogs remained at Site 1 and six at Site 3. The initial size of the population of wild dogs at Site 2 was 35 animals. The estimated initial populations of foxes were 9, 2 and 6 animals for Sites 1, 2 and 3 respectively.

As expected, the cumulative daily estimated number of dogs and foxes killed described asymptotic curves. The equations of the cumulative number of wild dogs killed (where y = the cumulative number of dogs killed and x = time in days) were;

$$y=16.97-17.31(0.81)^x$$

(97.3 % of variance accounted for) and;

$$y=16.51-15.29(0.824)^x$$

(94.8 % of variance accounted for) for Site 1 and 3 respectively and accumulated ANOVA showed that these curves were not significantly different ($F_{1,13}$= 1.88, P= 0.193). The populations of foxes at Sites 1 and 3 were shown by accumulated ANOVA to be significantly different ($F_{1,17}$= 12.32, P= 0.003). The functions of cumulative daily number of foxes killed were;

$$y= 5.720- 4.47(0.552)^x$$

(71.4 % of variance accounted for) at Site 1 and;

$$y= 5.023- 5.46(0.377)^x$$

(96.0 % of variance accounted for) at Site 3.

3.3.3 Bait Uptake

Poisoned baits were exposed for 691 bait nights at Site 1 and 997 bait-nights at Site 3 (Table 3.2). By the fifth day of poisoned-baiting, 85 % of all the baits that were removed by wild dogs had been taken at Site 1 and 84% had been taken at Site 3. At Site 1, 84% of all of the baits removed by foxes had been taken in the first two days and at Site 3 all removal of baits by foxes occurred in the first three days. At Site 1, one bait was eaten by a fox without consuming the 1080 tablet. Some bait-stations were visited by wild dogs without the bait being consumed (11 at Site 1 and 63 at Site 3). As dogs were progressively removed from the population at Site 3, the ratio of visitation without consumption of the bait to visitation with consumption increased from 1 visit without consumption: 12.25 baits removed to 1 visit without consumption: 0.4 baits removed. Six bait-stations at Site 1 were visited by foxes that did not remove the bait, and at Site 3, one bait-station was visited by a fox without the bait being removed.

Very few baits were removed by non-target animals (Table 3.2). Spotted-tailed quolls and cats were present at all sites before and after baiting but the frequency of

interference with bait-stations was so low (maximum frequency= 0.33 visits to bait-stations per 100 bait-nights) that no conclusions could be drawn about the abundance of these animals.

Table 3.2. Uptake of poisoned baits by target and non-target animals during a replacement-baiting program using 1080 baits. Where tracks were not differentiated into species the animal removing the bait was recorded as 'Unidentified'. A further two baits were removed from bait-stations by birds and deposited a few metres away.

Species	Site 1	Site 3
Wild dogs	33	112
Red fox	43	14
Feral cat	0	0
Spotted-tailed quoll	0	1
Possum (*Trichosurus* sp.)	0	1
Birds (Corvidae)	2	0
Unidentified	8	6
Bait putrefied	2	0
Total bait-nights	691	997

The removal of multiple baits by single wild dogs and foxes was apparent through the removal of sequences of baits at both sites. In some cases it was possible to confirm this by following the footprints of one or more animals between bait-stations. Using the technique outlined in the methods, I estimated that the maximum number of baits that could have been removed by a single wild dog was 21 (≈735g over 5.25 km of track), and a single fox could have removed up to 4 baits (140g over 1.5 km). Both of these estimates are plausible in the light of other research. Bird (1994) observed one dingo eat 1, 500 g of meat baits at one waterhole in arid South Australia during an acute food

shortage. The daily food consumption of red foxes has been estimated as approximately 372-450 g (Lockie 1959; Saunders *et al.* 1993). My estimates most likely exaggerate the number of baits that were taken by one animal. Given an average walking speed of 3 km hr^{-1}, it would take a single dog 1.75 hrs to consume 21 baits by which time approximately 42 lethal doses would have been consumed.

3.4 Discussion

3.4.1 Efficacy of Replacement-Baiting

Baiting intensity is dependent on four factors; the number of baits used, the size of the area to be baited, and the abundance of the target population and competitors for baits. The availability of baits to target animals is best expressed as the number of baits available to targeted animals in relation to the density of the targeted animal. It is not always possible to estimate the density of wild dogs (e.g. Bird 1994; this study), in which case it is preferable to express the number of baits that are available as a number per targeted animal (e.g. Thompson and Fleming 1994). This is often overlooked when comparisons are made between studies and can lead to erroneous conclusions as to the efficacy of baiting programs.

In my experiment, the strategy of replacement-baiting was efficacious. The reductions in the abundance of wild dog populations at both treatment sites (Table 3.1) were significant both statistically and biologically. My results (mean reduction of 76%) were similar to reductions achieved with aerial baiting (mean of three trials= 75%) in north-western Western Australia by Thomson (1986). The replacement-baiting program obtained results that were similar to those of Best *et al.* (1974) and greater than those achieved with ground baiting by McIlroy *et al.* (1986a). The availability of baits was greater in the replacement-baiting program than in McIlroy *et al.*'s (1986a) study because the number of baits was held constant in the replacement-baiting. Also, very few baits were taken by non-target animals in this trial whereas McIlroy *et al.* (1986a) found that a large proportion of baits that were removed were taken by birds (20-45% of baits). As fewer baits were removed by other animals in my study, more were available to the target animals than in McIlroy *et al.*'s (1986a) study.

The relatively small number of baits available to each wild dog in the studies of McIlroy *et al.* (1986a; 1986b) and Bird (1994) may have contributed to the lower reductions in the abundance that their studies showed. McIlroy *et al.* (1986a) estimated that 27 wild dogs were targeted by their program that consisted of 160 baits. However, only 48 of those baits were available to wild dogs (1.78 baits per dog) because the remainder were removed by other species. Bird (1994) used 430 baits for a population of 3-400 dingoes (1.08- 1.43 baits per dog). On the first day of my experiment, 4.18 baits per dog were available at Site 1 (after accounting for removal of baits by foxes) and 4.05 baits per dog were available at Site 3. As dogs are removed from the population, the relative availability of baits per animal density of a replacement-baiting program increases because the number of baits is held constant and the number and density of dogs and their competitors (foxes) decreases. With replacement-baiting, the probability of remaining target animals encountering baits increases with time, whereas the equivalent probability in a single-bait placement remains constant or declines.

Another explanation for the efficacy of replacement-baiting is that the baits offered during the before-baiting index, although different to the poisoned baits, may have increased the acceptance of poisoned baits by target animals and maximised the effectiveness of the replacement-baiting (Thompson and Fleming 1994).

The cumulative number of wild dogs killed described similar curves for the two treatment sites. As the replacement-baiting continued, fewer animals were removed each day and an asymptotic frequency-curve was described, indicating that the maximum level of removal was approached. The remainder of the population appeared to be less susceptible to baiting and this was implied by the increasing ratio of visitation without consumption that was demonstrated at Site 3. Despite differences in wild dog abundance at each site, as indicated by the indices, a similar proportion of both populations was killed.

Foxes confound baiting programs for wild dogs by removing baits targeted for wild dogs (McIlroy *et al.* 1986a). By replacing baits as they are removed by foxes or dogs this problem can be overcome. Replacing baits until bait-uptake ceases, or almost

ceases, allows for the maximum removal of bait-susceptible target animals in the shortest time. Conversely, if the objective of the control program is to remove foxes but with lesser impact on the abundance of a co-existing dingo population, bait-stations may be baited for a few days only. At the third day of baiting in this trial, 50- 56 % of the wild dogs that were susceptible to baiting had been removed whereas 83- 100 % of the susceptible foxes were removed. That foxes find and remove baits before wild dogs where the species co-occur may result from the smaller home ranges of foxes and their more catholic diet.

Foxes removed the majority of the baits during the first part of McIlroy *et al.*'s (1986a) trial and this pattern was reflected at Site 1 where fox numbers were highest. In my experiment this sequence of removals did not impinge on the efficacy of the replacement-baiting to control wild dogs. This is because, although more baits were removed by foxes than dogs at Site 1 (Table 3.2), more dogs than foxes were killed over the period of the baiting (Section 3.3.2).

The significant difference in accumulated ANOVAs performed on the cumulative number of foxes removed was expected. Foxes were still removing baits on the seventh day at Site 1 where foxes were more common, whereas no baits were removed after the third day at Site 3. However this conclusion must be viewed with caution because there were few foxes at either site.

In this study, the populations of foxes were small and the reduction in the fox population achieved by replacement-baiting was greater than that reported by Thompson and Fleming (1994) in agricultural lands (69.5 %). Algar and Kinnear (1992), using aerial baiting with 1080 baits distributed at a rate of 6 baits km^{-2}, achieved a reduction of 91 % in the abundance of foxes in a study in Watheroo National Park, Western Australia. This result is comparable with that obtained with replacement-baiting in my study.

Although my trial was conducted in hot and humid weather, only two of the manufactured baits putrefied during the trial. This implies that, to further minimise the risk to non-target animals, manufactured baits that remain after a baiting program should

be collected and disposed of by burning or deep burying. Meat baits buried contemporaneously at another site became putrefied within three to four days and were completely decomposed within five to six days. Replacement-baiting programs using meat baits and conducted in summer may require the replacement of all baits every three days to ensure that the baits are fresh.

3.4.2 Estimates of Population Abundance

Although the difference was not significant, the after-baiting index at Site 2 was 17.2 % higher than the before-baiting index. This may indicate that animals could have immigrated from surrounding areas or resident animals which were previously undetected had begun to use that part of their home ranges that were included in the bait-station transects. These explanations are supported by the observation that the two dogs killed at Site 3 on the last day of the baiting, visited bait-stations at the end of transects on the edge of the study site and removed baits three days after the previous kills. This indicates that these animals may have been immigrating into adjacent vacated home ranges or investigating the absence of neighbours. Another explanation is that the method is not sufficiently precise and a Type II error had occurred.

The significant *t*-statistic for the change in fox abundance indices at the nil-treatment site may have been an artefact of the low number of animals. McArdle *et al.* (1990) observed that the variability of estimates of population size are not independent of population size. Variances are often underestimated at lower population densities, as represented at Site 2 by smaller mean indices, and increase the likelihood of Type I errors.

3.4.3 Replacement-Baiting and Non-Target Animals

In this trial, where baits were buried, only two poisoned baits were removed by birds (Corvidae). This low rate of removal by birds may have been because the baits were buried (Allen *et al.* 1989) and because the baits were dyed green (Rathore 1985; McIlroy *et al.* 1986b). In contrast, the study of McIlroy *et al.* (1986a) where baits were laid on the surface, showed that a large proportion of baits were removed by birds. Although corvids are potentially at risk if they consume the tablet containing 1080 from within a bait

(McIlroy 1984; 1986), an equal risk is posed by birds that may remove baits and carry them to other locations where baiting is not desired. The corvids that were present at the study sites, including magpies (*Gymnorhina tibicen*), pied currawongs (*Strepera graculina*) and Australian ravens (*Corvus coronoides*) are regarded as common and the poisoning of a small number would not impact on the viability of total populations. There were more opportunities for visitation to bait-stations by birds (i.e. more bait-nights), but replacement-baiting, as used in this trial, resulted in a lower risk of removal of baits by birds than McIlroy *et al.* (1986a) and Allen *et al.* (1989) demonstrated for baits laid on the surface of the ground. The control of foxes may be beneficial to other bird populations (McIlroy 1984) and so the small risk that replacement-baiting presents could therefore be regarded as acceptable.

The methodology failed to index spotted-tailed quoll populations because the number of interactions with bait stations was very low (9 interactions in a possible 6806 bait-nights). Baiting with 1080 potentially poses a risk to individual quolls (McIlroy 1986; Fleming and Parker 1991) but it is unclear whether populations are at risk. One poisoned bait was removed by a quoll at site 3 and, given the dose of 1080 in the bait, the animal had an approximately 50% chance of being fatally poisoned (McIlroy 1981). Because of this, the replacement-baiting in this trial could not have affected quoll populations. However, caution is required in extrapolating this result to other sites because the manufactured bait used in the trial may have been less attractive to quolls than the meat baits that are most commonly used in ground baiting programs. Quolls were still present after baiting at all sites. While quolls are listed as Vulnerable and Rare on Schedule 12 of the *National Parks and Wildlife Act* (1974), the conservation status of the studied populations was not known. The treatment sites had been baited for the control of wild dogs over many years and quolls were still present and breeding (young were observed at Site 3). Although very few quolls visited bait-stations in this trial, other researchers, using different methods (P. Catling pers. comm.; Catling and Burt 1995), indicated that quolls were relatively abundant at Site 2 and 3 in March 1988. Further research is required to assess the effect of ground baiting programs and replacement-baiting on the abundance of populations of quolls.

One possum (*Trichosurus sp.*) removed a bait and was probably killed (LD_{50} for brushtailed possum (*T. vulpecula*)= 0.67 mg 1080 kg^{-1}, McIlroy 1986 Accessory Table 4). Neither *T. vulpecula* nor the mountain brushtail possum (*T. caninus*) are listed as Vulnerable or Rare under Schedule 12 of the *National Parks and Wildlife Act* (1974) and both are common in the region (Smith *et al.* 1992). The impact of the replacement-baiting program on *Trichosurus* populations was negligible.

4. The Efficacy of Aerial Baiting with 1080-impregnated Baits

4.1 Introduction

Aerial baiting, using fixed-wing aircraft and 1080-poisoned meat baits, has been demonstrated to be an efficient and cost-effective method for controlling dingoes in the pastoral zone of north-western Western Australia (Thomson 1986). In three trials in 1980 and 1981, aerial baiting was shown to reduce the abundance of wild dog populations by 100%, 63% and 62%. A similar trial in 1985 reduced the number of radio-collared wild dogs by 85% (Thomson and Marsack 1992). Thomson and Marsack (1992) also recorded a range of changes to the abundance of wild dogs (6- 80% reductions) in the Nullarbor area as the result of aerial baiting with 1080-poisoned baits. Bait type and the age and social status of the targeted dogs appeared to affect the efficacy of the baiting program (Thomson and Marsack 1992). McIlroy *et al.* (1986a) reported that a ground-baiting program in south-eastern Australia reduced wild dog populations by 22% and questioned the efficacy of aerial and ground-based 1080-baiting programs in eastern Australia.

Helicopters have been shown to be more suitable than fixed-wing aircraft for the accurate placement of baits in the temperate rangelands of north-eastern New South Wales (Thompson *et al.* 1990). Aerial baiting with helicopters has been widely practised for controlling wild dogs in these lands since 1985 (Chapter 1). However, the effectiveness of aerial baiting in reducing the abundance of wild dogs in the temperate rangelands of north-eastern New South Wales has not been evaluated. The focus of the experiment reported in this chapter was to measure the reduction in the abundance of wild dogs achieved by aerial baiting with helicopters, in north-eastern NSW. Crude estimates of population size and density are made for wild dogs in the study area, and the use of corrected indices is discussed.

4.2 Methods

4.2.1 General

To determine the efficacy of aerial baiting for the control of wild dog populations, the relative abundance of wild dogs at one site was determined before and after the

treatment (aerial baiting), and compared with the concurrent relative abundance of wild dogs at a second, untreated site.

Two sites, Sites 4 and 5, were chosen, one where wild dog control by aerial baiting was routinely conducted (Site 4) and one which was not baited (Site 5) (see Chapter 2.1.2 and Fig. 2.2 for details). The study sites were approximately the same size so that the number of wild dogs that could be supported were approximately equal. However, the relative abundances of prey at the two sites was not known.

4.2.2 Indices of Wild Dog Abundance

The methods described in Chapter 2.2.3 were used to obtain indices of the abundance of wild dogs at both of the study sites. In 1991, surveys were walked along spurs and ridges, where the detection of sign was difficult, and along valley floors. Transects in 1992 and 1993 were only walked along the valley floors, where tracks were readily discernible and identifiable in the soil. The same paths and cattle pads were walked on each occasion in 1992 and 1993.

All bar one of the indices of wild dog abundance were collected during the breeding period (Catling 1979; Thomson 1992b), the second of the after-baiting walks in 1993 coinciding with the birth and early lactation of some animals (nursing period I in Thomson 1992b). As movements are reduced in nursing period I in comparison with the breeding period, the effect of this would be to reduce the index for the second of the two after-baiting walks at Site 5 in 1993.

In 1991 the transects were walked once before and once after baiting, and the sign-indices were recorded only as SFs. The indices were not standardised for sightability of tracks. In the following two years, the abundance indices were taken both as SFs and CIs.

4.2.3 Efficacy of Aerial Baiting

The efficacy of each annual baiting program was assessed by the index-manipulation-index method of Caughley (1980; Caughley and Sinclair 1994), where the

CIs acquired before baiting were contrasted with those found after baiting. "Efficacy" was taken as the proportional change in the indices of wild dog abundance, a greater reduction in index being more efficacious than a smaller reduction.

At Site 4, CIs were collected on two occasions before and twice after the baiting program in 1992. The second of the before-baiting indices was taken three weeks after the first index. This allowed for rain, wind and cattle movements to erase the tracks recorded during the first transect. The same procedure was followed for the after-baiting indices. Four CIs were collected at Site 5 and the collection of these was concurrent with those of Site 4. This procedure was repeated at both sites in 1993.

The first of the after-baiting CIs taken at Site 4 in 1992 was later discarded because one month had not elapsed after the baiting. Thomson (1986) indicated that dingoes in Western Australia were killed up to seven weeks after baits were distributed. However, in eastern Australia most baits are removed within a week of bait-placement and 99% of baits are removed within one month of placement (McIlroy *et al.* 1986a: Saunders and Fleming 1988). Therefore, one month was left between the end of baiting and the commencement of after-baiting indices.

The general hypothesis to be tested was H: $\mu_{after} < \mu_{before}$, i.e. the abundance of wild dogs was less after baiting than it was before baiting. To compare the impact of baiting on the wild dog populations at Site 4 with those in the untreated Site 5, we used Randomised Intervention Analyses (RIA) of time series data (Green 1977; Carpenter *et al.* 1989). In the general case RIA compares changes in a manipulated ecosystem with an undisturbed reference system, and uses bootstrapping to estimate the probability of those changes occurring by chance. In this experiment, with a maximum of eight indices (four treated and four un-treated) all possible differences were calculated and the exact probabilities determined.

Using RIA, the changes in CI and SF within the baited area were contrasted with changes at the similar nil-treatment site to determine whether a change in the abundance of wild dogs had occurred. Comparisons (within sites) between before- and after-baiting

SF indices were also conducted with RIA. RIA could not be used to test whether the abundance of wild dogs before baiting varied between years, nor could RIA be used to compare the abundance of wild dogs between sites. This was because the minimum probability of these contrasts occurring by chance was $P= 0.16$ and therefore the traditional level of significance ($P< 0.05$) was unattainable. To determine whether the magnitude and direction of the two measures of abundance changed simultaneously, the correlation between SF and CI values was calculated using GENSTAT5. Because the CIs and SFs were collected and analysed as a time series it is inappropriate to use the before- and after-baiting indices for each year as replicates (see Chapter 2). Therefore the magnitude of the changes in abundance are expressed as a range of percentage differences between before and after indices.

4.2.4 Estimates of Population Size

In 1992 and 1993 attempts were made to estimate a minimum number of wild dogs alive at Site 4 after the aerial baiting. On each of the after-baiting transects at the same place and time (approximately 20.00 hours), I simulated the howls of wild dogs in order to elicit a response from any wild dogs that were within earshot. The number of individual dogs that responded would give a crude minimum number of wild dogs known to be alive after the baiting. Using the minimum number of dogs known to be alive after the baiting in (N_2) and the indices taken before (I_1) and after the baiting (N_2) a minimum number of dogs present before baiting (N_1) was calculated;

$$N_1 = I_1 N_2 / I_2.$$

The number of animals (N_1) was then divided by the before-baiting indices to obtain a range of numbers of animals per unit of the CI (Thompson and Fleming 1994). To obtain estimates of the population at the nil-treatment site, Site 5, the before-baiting CIs were multiplied by N_1 / I_1 for Site 4. Density estimates were made using the ranges of population size and the estimated area of each site. These estimates were made assuming that the relationship between the index (CI) and actual population size was constant across sites and between years. The estimates of population size and density were expected to be conservative. Not all wild dogs that were present responded to the simulated howls because of the limited range over which the simulated howls were

projected, and if more than one dog responded in unison (see Corbett and Newsome 1975) this event was recorded as one animal.

4.2.5 Bait Distribution

Baiting with 1080-impregnated meat baits (Table 4.1) occurred in late April in each year. Each bait (mean mass 203.5 g (s.d.= 39.4), Tony Barnes unpublished data) was injected with 6.0 mg of 1080. In 1991 the valley floors, major ridges, dog-proof fencelines and major tributaries within the Aberfoyle River gorge were all baited using a helicopter. The 1993 baiting was essentially the same with minor variation in total bait quantity, and the baiting rate was approximately 4 baits km^{-2} in both years. In 1992, only the Aberfoyle valley floor was baited from the air but fewer baits were placed (≈ 786 baits): the remainder were placed from motorbikes along some of the more accessible ridges and major tributaries. This took longer than aerial baiting and the baiting was not completed until one month after the aerial baiting.

Table 4.1. Bait quantities and estimated number of baits for aerial baiting programs of the Aberfoyle River gorge (1991-1993). In 1992, only 160 kg (≈ 786 baits) were aerially-placed, the remainder being ground-placed over a one-month period. n= estimated number of baits.

Year	Bait quantity (kg)	n
1991	730	3587
1992	509	2483
1993	690	3391

4.3 Results

4.3.1 Indices of Wild Dog Abundance

Both the CI (Table 4.2 and SF (Table 4.3) measures fluctuated in the same direction and those fluctuations were of similar magnitude (r= 0.909, d.f.= 14, P< 0.01).

The CIs taken before baiting, were between 16.1% and 54.2% higher at Site 5 than at Site 4 indicating a greater before-baiting abundance of wild dogs at the nil-treatment site.

Although the work of Thomson (1992d) suggested that movements of lactating female wild dogs were restricted during the first nursing period, there was no evidence that the second after-baiting walk in 1993 at Site 5 was affected by changes in movements. The CI of the second walk was similar to that of the first walk (Tables 4.2 and 4.3).

Table 4.2. Corrected density indices (CIs) of wild dogs before and after aerial baiting with 1080 meat baits, 1992 and 1993. n.r.= no index recorded, see text. Site 4 was the treatment site and Site 5 was untreated.

	Density index (CI)			
	Treatment site		Nil-treatment site	
Year	Before baiting	After baiting	Before baiting	After baiting
1992	1.579	0.281	1.879	2.394
	1.707	n.r.	2.238	1.054
1993	1.082	0.364	2.362	1.716
	1.774	0.314	2.935	1.728

Table 4.3. Density indices (SFs) of wild dogs before and after baiting with 1080 meat baits, 1991- 1993. Indices are expressed as sets of footprints observed per km of transect. n.r.= no index recorded, see text. Site 4 was the treatment site and Site 5 was untreated.

	Density index (SF)			
	Treatment site		Nil-treatment site	
Year	Before baiting	After baiting	Before baiting	After baiting
1991	0.804	0.084	1.050	1.289
1992	7.886	0.704	5.629	7.969
	5.560	n.r.	7.000	3.846
1993	6.122	1.462	8.390	6.560
	10.750	1.225	10.781	6.639

4.3.2 Efficacy of Aerial Baiting

In 1991 baiting was intensive and the density index (SF) for wild dogs in Site 4 was substantially reduced. Substantial reductions in the SF and CI indices were apparent in 1992 and 1993 (Tables 4.2 and 4.3). In 1992 the changes in CI in Site 4 represented a reduction in the wild dog population of between 82.3% and 84.5%. The change in CI at Site 4 in 1993 was between 66.3% and 82.3%. The RIA (Table 4.4) showed that the differences between the CI indices at the treatment and nil-treatment sites were not the result of chance. Differences in the SF indices were large and significant (Table 4.4). At Site 4, the SF index was reduced by 89.6% in 1991, by between 87.3% and 91.1% in 1992 and between 76.1% and 88 6% in 1993.

Table 4.4 Randomisation intervention analysis (RIA) of the difference in the indices of the abundance of wild dogs at a site manipulated by baiting and an untreated site. Tabulated values are the mean differences between the indices of the treatment site, Site 4 and those of the untreated control, Site 5.

Index	Before-baiting mean difference	After-baiting mean difference	Difference between before- and after-	*P*
CI	0.887	1.626	0.739	0.029
SF	0.371	4.746	4.375	0.029

4.3.3 Crude Estimates of Population Size

On only one of the four after-baiting transects did wild dogs respond to my simulated howls. In 1992, four wild dogs responded to howls. The estimated minimum number of wild dogs present at Site 4 in 1992 before baiting was between 22.5 and 24.3 animals, and N_2/I_2= 14.235 dogs / unit of CI. No response to simulated howls was elicited in 1993. The before-baiting indices for Site 4 in 1993 were multiplied by the N_2/I_2 value for 1992 giving a crude estimate of between 15.4 and 25.3 wild dogs. At Site 5, the population size in 1992 was between 26.8 and 31.9 wild dogs, and in 1993 was between 33.6 and 41.8 wild dogs. Using the pooled estimates for population size in 1992 and 1993, the population density of wild dogs at Site 4 before the aerial baiting was estimated between 0.10 and 0.17 wild dogs km^{-2}. The minimum density at Site 5 was between 0.19 and 0.30 wild dogs km^{-2}.

4.4 Discussion

4.4.1 Indices of Wild Dog Abundance

The indices of abundance (CIs) at Site 5 were higher than Site 4 in both years, showing that the abundance of wild dogs was greater in the nil-treatment site. The abundance of wild dogs at Site 5 in 1993 was 28.7% greater than in 1992 but the

difference was within the bounds of 2 standard errors, implying that the population had not changed significantly. The population abundance before baiting at Site 4 in 1993 was similar (-13.1 %) to that of 1992 indicating that repopulation had occurred at some time after the 1992 baiting.

Both methods used to index the abundance of wild dogs in this study detected gross changes in abundance after baiting. The proportional changes in abundance in the CI index were mirrored in the SF index, although the SF gave slightly larger differences caused by baiting and were more variable (see Tables 4.2 and 4.3). In both cases, a substantial biological change was reflected as a statistically significant result (Carpenter *et al.* 1989). There is argument that the significance tests for changes to large-scale systems should be less stringent (e.g. Stewart-Oaten *et al.* 1992) so that Type I errors are avoided.

Although useful indices of the abundance of wild dogs were provided by both techniques, the CI is potentially more useful. Because the CI accounts for variability in the tracking substrate and conditions, comparisons between sites using this method are more acceptable. Without standardisation such comparisons rely on the untested assumption that tracking conditions at each site were uniform. In this experiment, the CIs were less variable and, as reflected by the RIA, were therefore more sensitive to changes in abundance than the SF method. However, between-season comparisons of any index reliant on the indirect detection of the activity of wild dogs are likely to be unreliable. This is because wild dogs exhibit different levels of activity and movement in different seasons (Thomson 1992b; 1992d).

Standardisation of indices of the abundance of wild canids allows comparisons between sites and between years (Thompson and Fleming 1994: Fleming and Thompson 1995). Between-year contrasts of relative abundance at one site are possible if the indices are determined during the same time of year. Comparisons of the relative abundance of wild dogs between sites are only possible when the sites are topographically similar and if the surveys are done concurrently.

While the methods that were used here were able to detect gross changes in abundance, the exact relationship between actual density and indices of the abundance of wild dogs would require the experimental manipulation of a population of known size.

4.4.2 Efficacy of Aerial Baiting

The use of aerial baiting to reduce wild dog populations was found to be efficacious in 1991 and 1993. The reduction in SF index at Site 4 in 1991 was substantial and was not mirrored at Site 5. However, because the transect-counts were not standardised or replicated, the real magnitude of the change would be uncertain without corroborating evidence. In 1992, the combined aerial and ground baiting programs achieved a similar population reduction in SF to the other two years. The changes in abundance indices of wild dogs (SFs) at Site 5 in 1991 were small over the same period (22.8% increase in index). The observed changes in SF in Site 4 were too large not to have reflected actual changes in the population abundance.

While the RIA does not demonstrate causality, there were no ecological explanations for the significant and rapid changes to the indices of abundance of wild dogs at Site 4 other than aerial baiting. The CIs for 1992 and 1993 showed reductions in the abundance of wild dogs at the treatment site of similar, but slightly smaller, magnitude to the SF index. The untreated site also showed a small and insubstantial reduction in CI and SF at the after-baiting surveys. The magnitude of the changes in both abundance indices at Site 4 were similar for each year and could only have been attributable to the perturbation caused by the baiting.

The proportional reductions in the abundance of wild dogs achieved in my experiment (between 66.3 and 84.5% change in CI) were similar to those found in the Fortescue region by Thomson (1986) ($\bar{x}$= -75%, s.d.= 21.7) and Thomson and Marsack (1992) (85%). Thomson (1992d) estimated densities of between 0.035 and 0.225 wild dogs km^{-2} for the Fortescue region and this was roughly equivalent to the initial densities for my study sites (0.1- 0.3 wild dogs km^{-2}). The similarity of the efficacies of aerial baiting between my study and that of Thomson (1986) may therefore have reflected similar baiting intensities.

The reductions in the abundance of wild dogs in my experiment were greater than those recorded by Best *et al.* (1974) or McIlroy *et al.* (1986a) with ground baiting programs. However, fewer baits are used in ground baiting programs than are commonly used for aerial baiting. For example, McIlroy *et al.* (1986a) used 6.3 baits km^{-1} in their ground-based baiting program whereas aerial baiting programs in north-eastern New South Wales use 40 baits km^{-1} (NSW Agriculture unpublished records). As mentioned in Chapter 3, the efficacy of baiting programs is related to the baiting intensity, among other things. The crude estimates of minimum population size calculated in this chapter allow the calculation of baiting intensity for Site 4. A maximum of between 56.2 and 60.7 baits were potentially available to each wild dog in 1992, and between 73.7 and 121.1 baits per wild dog in 1993 (assuming that up to 45% of baits were taken by birds, McIlroy *et al.* (1986a) and ignoring those baits removed by foxes). In Thomson's (1986) trial in October 1980 where all the radio-collared wild dogs were poisoned, approximately 100.2 baits were available per wild dog. The baiting intensity at Site 4 in 1992 and 1993 was higher than in McIlroy *et al.*'s (1986a) study of ground baiting (3.3 baits were available per wild dog if baits removed by foxes are ignored or 1.8 baits per wild dog when including baits taken by foxes), and may explain the greater reduction in the abundance of wild dogs shown in my experiment.

Newsome *et al.* (1972) and Best *et al.* (1974) both suggest that the availability of alternative prey may affect bait uptake by canids and hence affect the success of baiting campaigns. In my study, the abundance of macropod prey was significantly higher in the treatment area than the nil-treatment area (Chapter 6) while the relative abundance of wild dogs was the reverse. This would imply that prey abundance was not limiting at the treatment site and that the uptake of baits by wild dogs was independent of prey abundance.

The CIs of Site 4 were similar between years indicating that the abundance of wild dogs before baiting was similar between years. Given that a substantial reduction in the wild dog population had occurred because of the baiting programs, the re-establishment of the population by the following year's baiting indicates that baiting programs should be conducted at least annually.

Not all wild dogs were killed by the aerial baiting program. This was expected because not all carnivores will take baits (Thompson and Fleming 1994) and because of the high number of baits that would have been taken by foxes or removed by birds (Allen *et al.* 1989). Quolls (*Dasyurus* spp.) may also take baits on rare occasions (see Chapter 3). As quolls are the non-target predators most at risk from 1080-poisoned meat baits (McIlroy 1986; Fleming and Parker 1991), further study is required to determine the effect of aerial-baiting on the abundance of populations of quolls.