CHAPTER 3

BAIT CACHING

3.1 Introduction

The effectiveness of poison baiting campaigns relies on presenting attractive and palatable bait. Baits should be attractive to ensure that the target species will find the bait, and should be highly palatable to ensure that the animal will consume the bait and the contained toxin (Allen *et al.* 1989). Traditionally, studies have assessed the palatability of bait types through investigating and comparing the rate or proportion of each bait type removed by the target species. This fails to account for any difference between attraction and palatability since it does not assess the fate of bait after it is removed from the station. For example, Saunders *et al.* (1999) reported that a significant proportion (10%) of Foxoff® baits removed by foxes are not consumed. Therefore, removal of bait without immediate consumption should be considered when investigating the potential of bait types in baiting campaigns (Van Polanen Petel *et al.* 2001).

Caching or hoarding is defined as handling food to conserve it for later use (Vander Wall 1990) and offers the participant greater ability to control food availability spatially and temporally (Maccarone and Montevecchi 1981). Caching may be a means of securing food from the attention of competitors, including other foxes (Macdonald 1987). Food preference is an important influence on the caching behaviour of individuals. Palatability influences caching behaviour; foxes are more likely to immediately consume preferred prey and cache less preferred prey (Macdonald 1976, 1977, 1987). This is supported by studies on bait types by Van Polanen Petal *et al.* (2001), who found that the preferred bait type presented to caged and wild foxes was eaten most and cached least.

Foxes are known to store food in preparation for periods of low food availability and periods when energy requirements are high, such as the birth of offspring (Macdonald 1977) and, in the higher latitudes, in preparation for winter (Maccarone and Montevecchi 1981). Caching can occur during periods of temporary food surplus (Macdonald 1976, 1977, 1987); there is evidence that even within foraging sessions food discovered before satiation is consumed (Henry 1986) whereas food discovered later is cached (Kruuk 1972). This suggests that caching intensity may increase when food availability is high, and/or nutritional demands are low.

As a result, caching behaviour is likely to vary seasonally. The intensity of caching is likely to be related to the availability of prey and nutritional status of the predator (Scott 1943; Macdonald 1976). Macdonald (1977) demonstrated that preference of individual foxes may change as a result of reproductive or nutritional circumstances. The nutritional and energy demands of foxes fluctuate as a result of the annual reproductive cycle. Foxes accumulate fat and protein reserves throughout the non-reproductive stage of the annual cycle, and deplete these reserves during the reproductive period (Winstanley *et al.* 1999). Reduced body fat levels relate to either reduced foraging activity or higher nutritional demands during the whelping and cub provisioning stage (Winstanley *et al.* 1999). It is difficult to interpret how these periods may influence preference and caching behaviour. Caching may be reduced when food is encountered during non-reproductive periods to accumulate body fat for periods of peak energy demand. Alternatively, reproductive periods may result in reduced caching of food since nutritional demands would be greatest at this time. Additionally, seasonal changes in available prey biomass may either promote or reduce caching when food is in surplus or deficit respectively. Caching behaviour may change as a result of these changes in foraging and nutritional demand. Any assessments of fox caching should, therefore, attempt to monitor fox caching behaviour over different seasons.

Caching could potentially reduce the safety, efficacy, and cost-effectiveness of control programs. There may be significant non-target implications when 1080 baits remain cached at the completion of baiting campaigns. Cached baits may pose a hazard to non-target animals that may recover the cache, exposing them to the toxin (Van Polanen Petel *et al.* 2001). Caches could remain hazardous for extended periods since they cannot be located and removed at the end of a control program (Thomson and Kok 2002). This is potentially hazardous to domestic animals such as working dogs that are used in previously baited areas. Similarly, caches may be located at considerable distances from where originally laid

(Saunders *et al.* 1999), and may be moved onto areas thought to be 'bait free'. The distance that baits are moved should be monitored to allow better formulation of distance restrictions for the placement of baits during baiting campaigns.

There may be implications for the success of baiting campaigns if cached baits remain in the field where immigrating or other foxes have access to these baits. 1080 will degrade with exposure with the soil and environment (see Chapter 2) and bait aversion may develop as a result of consuming a sub-lethal dose from degraded bait. This could reduce the effectiveness of future campaigns through making resident or immigrating foxes averse to consuming poison bait. Similarly, caching has implications for the effectiveness of oral vaccination campaigns; baits must be consumed within defined periods because of the limitations of the vaccine to initiate a sufficient immune response under environmental conditions (Macdonald *et al.* 1994; Pastoret *et al.* 1996).

Caching reduces the efficiency of baiting programs since a disproportionate number of baits are removed without immediate consumption. Monopolisation of baits by few individuals would reduce the effectiveness of baiting campaigns since these baits may be unavailable to other foxes to consume. This may reduce the overall efficacy of the baiting program, or mean that additional baits should be laid to target the remaining foxes in the population, reducing the cost-effectiveness. Caching therefore entails a 'waste' since baits are not used efficiently.

A recent survey of New South Wales Rural Lands Protection Boards (RLPB's) provides evidence that baiting is continuing to be the most popular control technique totalling 74% of control effort for management of foxes (West and Saunders 2003). Foxoff® are the most common bait type used in New South Wales, comprising over 48% of baits used in 2001 (West and Saunders 2003). Chicken wingettes are used predominantly in the southern areas of New South Wales, but their use has increased to 10% of RLPB's by 2001 since their introduction in 1998. Additionally they may be registered for use in Victoria in 2005 (C. Tan, Victorian Farmers Federation, pers comm. 2004). Day-old chicks are not a registered bait type for fox control in any Australian state or territory. Observations have shown that foxes find day-old chickens palatable (Macdonald 1977) and they are the recommended bait in the

Department of Environment, Food and Rural Affairs (DEFRA) in the United Kingdom for the distribution of rabies vaccines to foxes in the event of an outbreak.

Caching trials suggest that Foxoff® are readily taken by foxes but significant proportions may be cached (Saunders *et al.* 1999; Van Polanen Petel *et al.* 2001). Despite observations that wingettes are readily taken by foxes (T. Abblett, Wentworth RLPB pers comm. 2003), there has been no assessment of the palatability of wingettes. Day-old chickens may provide a highly palatable alternative but there is evidence to suggest that this palatability may change due to reproductive demands (Macdonald 1977). Wingettes, day-old chicks and Foxoff® should be assessed during different seasons to investigate their relative palatability, and if this palatability varies as a result of reproductive or environmental changes.

The objective of this chapter was to investigate bait caching by wild foxes with respect to the bait type and seasonal influences on caching. Additionally, the retrieval of caches per season and the distances that caches are made from the original bait station are investigated to help formulate strategies to improve the safety and efficacy of baiting programs during different periods throughout the year.

3.2 Methods

3.2.1 Study sites and seasons

Bait caching trials were undertaken at four sites on the central tablelands of New South Wales. The non-toxic baiting trials were undertaken on two properties "Larras Lake North" and "Fernleigh" which are situated near the locality Larras Lee, approximately 12 km north of Molong. The trials using 1080 baits were undertaken on another two sites; "Myrangle", situated west of Cumnock, approximately 30 km north-west of Molong, and "Nandillyan Heights", situated 7 km east of Molong. The properties are adequately spaced apart (>4 km) based on home range estimates (Saunders *et al.* 2002a) to ensure independence from foxes moving between sites.

Sites were chosen to represent mixed farming and grazing (sheep and cattle) properties typical of those situated on the central tablelands. All four sites had historically undertaken occasional fox baiting programs (less than one per year) but had not done so for at least 2 years before the commencement of the initial trial. Sites are primarily undulating to hilly areas of open grassland of native and improved pasture species intersected with patches of open woodland. At "Nandillyan Heights", "Larras Lake North" and "Fernleigh", the dominant association is the white box-apple box (*Eucalyptus albens* - *Eucalyptus bridgesiana*) community. Associated species include yellow box (*Eucalyptus melliodora*), blakelys red gum (*E. blakelyi*) and mugga ironbark (*E. sideroxylon*), with river red gum (*E. camaldulensis*) and river oak (*Casuarina cunninghamiana*) along the banks of streams (Dwyer 1978). At "Myrangle", grey box (*E. woollsiana*), narrow-leaved ironbark (*E. crebra*) and cypress pine (*Callitrus glauca*) replaced *E. bridgesiana* and *E. sideroxylan* (Dwyer 1978).

The caching trials were undertaken over three seasons, autumn, winter and spring. The non-toxic trials were undertaken at "Larras Lake North" and "Fernleigh" during autumn 2001, spring 2001, winter 2002 and spring 2002. The 1080 poison trials were undertaken at "Nandillyan Heights" and "Myrangle" during winter in 2001 and 2002.

The cumulative rainfall deficiency for the nearest weather station (Molong) is shown in Figure 3.1. This represents the difference between actual rainfall and the long-term median rainfall, providing an assessment of the seasonal conditions (Foley 1973).

3.2.2 Bait preparation and laying procedures

Baiting was undertaken based on recommended methods for laying baits on agricultural lands of New South Wales (Korn and Lugton 1990). Bait stations were spaced at least 200 m apart and usually placed adjacent to farm tracks and fencelines along a transect that encompassed representative habitats on each site. Bait stations were an approximate one metre diameter area cleared of grass and vegetative litter covered with sifted soil (1-2 cm thick) with a single bait buried 5-10 cm below the surface. Tracks and/or sign (e.g. scent, faeces) left on the station were used to identify the species visiting and/or removing the bait.

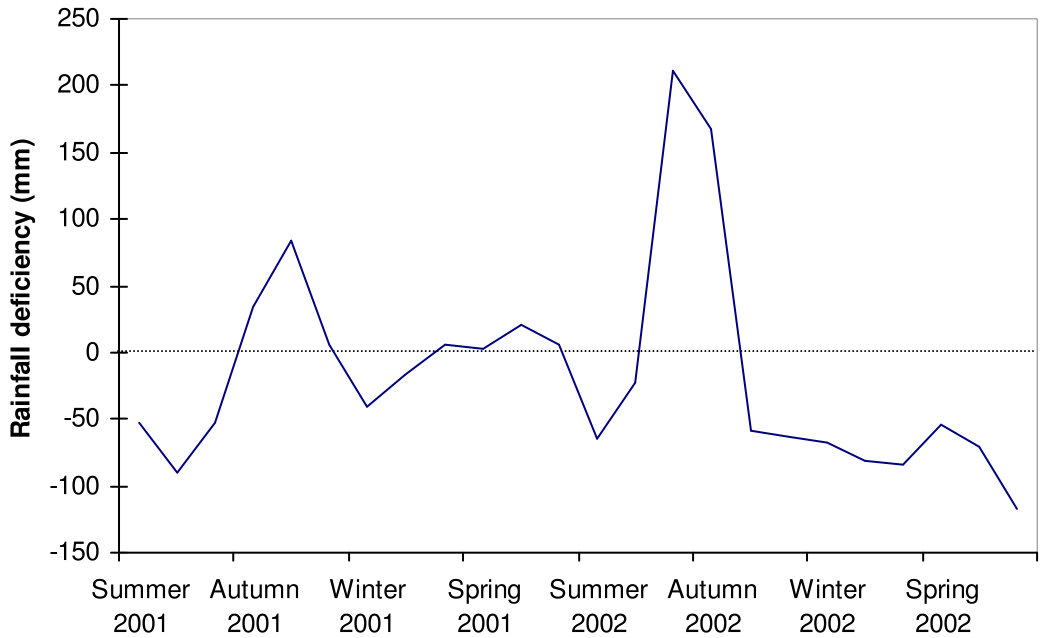

Figure 3.1: Cumulative rainfall deficiency (mm) (Foley 1973) for Molong weather station. Data sourced from the Bureau of Meteorology (2003).

To enhance subsequent uptake, all stations were free-fed with non-toxic bait without transmitter for a five to seven day period using one of three bait types. Baits were checked every one to two days during this period and any baits removed were replaced. Bait types were randomly allocated to bait stations in each trial period to reduce environmental factors resulting in greater uptake of one or more bait types. Following pre-baiting, a microtransmitter (150MHz, Sirtrack, Havelock North, New Zealand) was inserted into each bait. Transmitters were 1.5 x 3 cm in size and encased within epoxy resin to protect the transmitter from the weather and mastication by consumers. Previous studies incorporating transmitters in baits have shown no significant difference in the proportion of transmitter and non-transmitter baits taken by foxes (Saunders *et al.* 1999; Thomson and Kok 2002). Foxoff® baits were warmed sufficiently to soften and allow the bait to be moulded around the transmitter (adapted from Saunders *et al.* 1999). The transmitter was sewn into the abdominal cavity in the day-old chicken, and into the muscle between the radius and ulna bones in the wingette using monofilament nylon thread (4 lb breaking strain).

Methods were identical for all caching trials apart from the presentation of 1080 baits with the inclusion of the transmitters in the 1080 bait trials. 1080 baits were prepared using standard techniques (see Chapter 2) and contained a 3 mg nominal dose.

3.2.3 Bait uptake

At the two non-toxic sites, seasonal patterns in bait uptake were investigated through comparing the survival of the initial baits laid at the bait stations during the first five days of free-feed period. Following the initial trials, it became apparent that foxes would not locate all bait stations during the free-feed period. Additionally, some bait stations suffered severely from interference by domestic stock (sheep and cattle) and were abandoned. As a result, additional bait stations were free-fed in the following trials to allow those stations interfered by stock and/or showing low activity to be abandoned. This allowed the maximum benefit from the use of transmitters to investigate the proportion of bait caching in each trial. Apart from those abandoned or added, bait stations were kept constant for each trial following Trewhella *et al.* (1991) to ensure that any differences in bait uptake due to differences in the location of bait stations were minimised.

3.2.4 Bait consumption and caching

Following presentation of the microtransmitter baits, bait stations were checked daily for 10 consecutive days, and any bait removed tracked down. Following Saunders *et al.* (1999), each trial was undertaken for 10 days as a compromise between the duration of normal practice fox baiting programs (2-3 weeks), the labour required to check baits, and the transmitter battery life.

The fate of each removed bait was determined by tracking down individual baits on foot using a TR-4 receiver (Telonics, Arizona, United States) and hand-held Yagi antenna (Sirtrack, Havelock North, New Zealand). Transmitters that were found without the surrounding bait medium were assumed to have been eaten. Baits were recorded as cached if they were removed from the bait station and reburied or hidden elsewhere (Saunders *et al.* 1999; Thomson and Kok 2002). When baits were eaten a fresh bait with transmitter was replaced at the station. Cached baits were left at the cache site and checked daily until the end of the 10 day trial period when all baits and transmitters were recovered.

When located, the straight-line distance that baits were cached or eaten from their original location was paced and estimated in metres.

Spotlight counts were undertaken at both sites for three successive nights before the trial period to estimate fox density. These counts were undertaken with the aid of a 100 Watt spotlight from a four-wheel drive vehicle, along pre-defined transects.

3.2.5 Statistical analyses

Bait uptake

The Cox proportional hazard regression model (Cox 1972) was used to model the hazard function to determine whether the survival of bait at bait stations was influenced by the factors Season Year, Bait type and Site and the covariate Fox density. Fox density indices were calculated from the mean foxes seen per km of transect from 3 consecutive nights of spotlight counts on each site for the season when the trial was undertaken. This analysis allows for a baseline hazard function that is modified multiplicatively by covariates; this is particularly important when comparing covariates within populations since the effect of each covariate on survival can be determined. The results from the Likelihood ratio tests indicate whether there is a significant difference between the groups as tested (Venables and Ripley 2002). Factors and covariates within models were tested for significance through analyses of deviance procedures, non-significant factors were dropped from the models. Survival analysis was considered appropriate since baits presented at bait stations remain active or “alive” until taken by foxes when they became “dead”. To avoid bias associated with animals learning from continual replacement during free-feeding (Thompson and Fleming 1994), only the initial bait placed in a station was included in the analyses.

Bait caching

Given that bait stations were free-fed for a period before the inclusion of the transmitter baits, many bait stations had been located and/or regularly visited by foxes. Therefore visitation to and uptake of the transmitter baits is confounded by earlier visitation by foxes to the bait station. To account for this, the seasonal probability of a bait being cached is calculated from the transmitter baits that are removed by foxes i.e. the probability that foxes will cache the bait when it is removed from the station.

Logistic regression using generalised linear models (GLM) was undertaken to investigate the influences of relevant factors and covariates on the probability of bait being cached. Logistic regression was undertaken since it allows for meaningful biological interpretation when the response variable is dichotomous (in this case either cached or eaten) (Lemeshow and Hosmer 1998). Residual plots were undertaken to examine for heterogeneity of variance (Snedecor and Cochran 1989). A stepwise regression procedure was followed from the initial maximal model to produce the minimal adequate model as determined through the minimal Akaike's Information Criterion (AIC) with respect to the principle of parsimony (Akaike 1973; Burnham and Anderson 1992). Where necessary, AIC were corrected for over-dispersion through quasi-likelihood theory by including a variance inflation factor or interpreted using F-ratios (Crawley 2002). Variables were tested for significance through analysis of deviance, and coefficients through z statistics. The effect of site, season/year, night of trial, days since the bait was laid, bait type, fox density during season of trial, and bait removal during the free-feed period were examined for their effect on the response variable, a bait being cached when initially taken (see Table 3.1 for summary of variables). Biologically plausible second-order interactions were also included and tested for significance. To account for any differences in caching behaviour due to different fox densities, an index of fox density was included in the model.

Table 3.1: Description of variables used in the GLM to identify the main determinants of caching.

Variable (category)	Range of variable	Description
Cached (response)	0 or 1	0 = eaten 1 = cached
Days since laid (covariate)	0 - 6	Number of nights the bait has been presented following initial burial
Season Year (factor)	Autumn 2001, Spring 2001, Winter 2002, Spring 2002.	Season/Year that trial undertaken
Bait type (factor)	Foxoff®, Day-old chick and wingette	Bait types tested
Site (factor)	Larras, Fernleigh	Properties where trials were undertaken
Fox density (covariate)	1.29 – 1.86	Mean foxes seen per km of transect driven from 3 observations
Number baits taken (covariate)	0 - 6	Number of baits taken by foxes and unidentified species from that station during the free-feed period

Cache recovery

Since transmitters were retrieved at the end of each trial period (10 days) the fate of all cached baits could not be monitored for uniform periods. A censored survival analyses was required to analyse the period of time that baits remained cached before being retrieved and consumed by foxes. Similar to the caching analyses, cached baits were classified as 'alive' until retrieved by foxes ('dead'). This analysis provides a baseline hazard function that is modified multiplicatively by covariates; this is particularly important when comparing covariates within populations since the effect of each covariate on survival can be determined. The results from the Likelihood ratio tests indicate whether there is a significant difference between the groups tested (Snedecor and Cochran 1989; Venables and Ripley 2002). Factors and covariates within models were tested for significance through Analyses of Deviance procedures; non-significant factors were dropped from the models.

Caching distances

The distance that baits were cached from stations were analysed through linear regression.

Cache depth

A linear regression model was used to determine if the depth that the non-toxic bait was cached was significantly influenced by the Season Year of the trial, site where the trial was undertaken, and bait type used.

Free-feeding

Linear regression was used to determine if the probability of a non-toxic or toxic bait being cached was influenced by the number of free-feed baits removed by foxes or unknown species at each station during the initial free-feed period.

3.3 Results

3.3.1 Bait uptake

From the initial baits laid at each non-toxic site during each trial, the percentage removed during the first five days for the free-feed period ranged between 20.8% and 85.0% (Table 3.2).

Table 3.2: The number of baits initially laid, number taken by foxes and percentage removed by foxes during the first five days of the free-feed period at each non-toxic site during each trial.

Site	Season Year	Number laid	Number Taken	Percentage removed
Fernleigh	Autumn 2001	24	9	37.5
Larras	Autumn 2001	24	5	20.8
Fernleigh	Spring 2001	43	31	72.1
Larras	Spring 2001	52	26	50.0
Fernleigh	Winter 2002	40	34	85.0
Larras	Winter 2002	46	24	52.2
Fernleigh	Spring 2002	36	26	72.2
Larras	Spring 2002	37	30	81.1

The survival of the free-feed baits initially laid in the bait stations was significantly influenced by the Site (χ^2 = 29.0, d.f. = 1, P <0.001) and the Season Year of the trial (χ^2 = 17.52, d.f. = 3, P <0.001). There was no difference in the survival rates of the bait types (χ^2 =2.7, d.f. = 3, P = 0.45). Relative fox density also significantly affected the survival of bait (χ^2 = 10.56, d.f. = 1, P =0.001), with decreased survival of bait with increasing fox density (β = -1.024, z = -2.82, P = 0.005).

The estimated survival curves for Season Year and Site are shown in Figures 3.2 and 3.3 respectively. Autumn 2001 showed a significantly greater survival than spring 2002 (β = 1.292, z = 2.64, P = 0.008) and winter 2002 (β = 1.074, z = -2.16, P = 0.03), but was not significantly different to spring 2001 despite indications that survival was greater (β = 0.936, z = 1.91, P = 0.06). Similarly, the hazard rate on Larras (β = -0.874, z = -5.59, P < 0.001) was significantly less than Fernleigh, indicating greater survival.

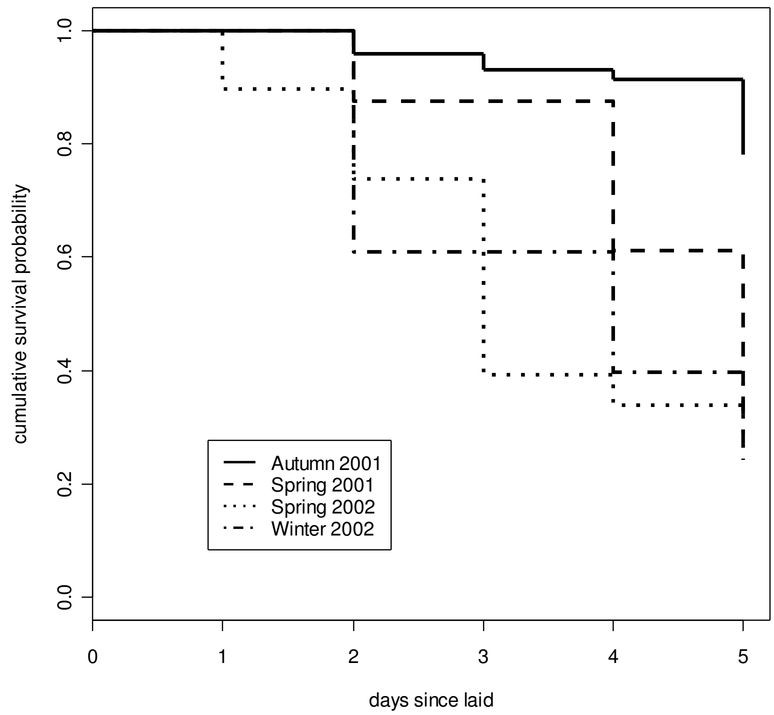

Figure 3.2: Survivorship of the initial baits laid for the Season Year of the non-toxic trials.

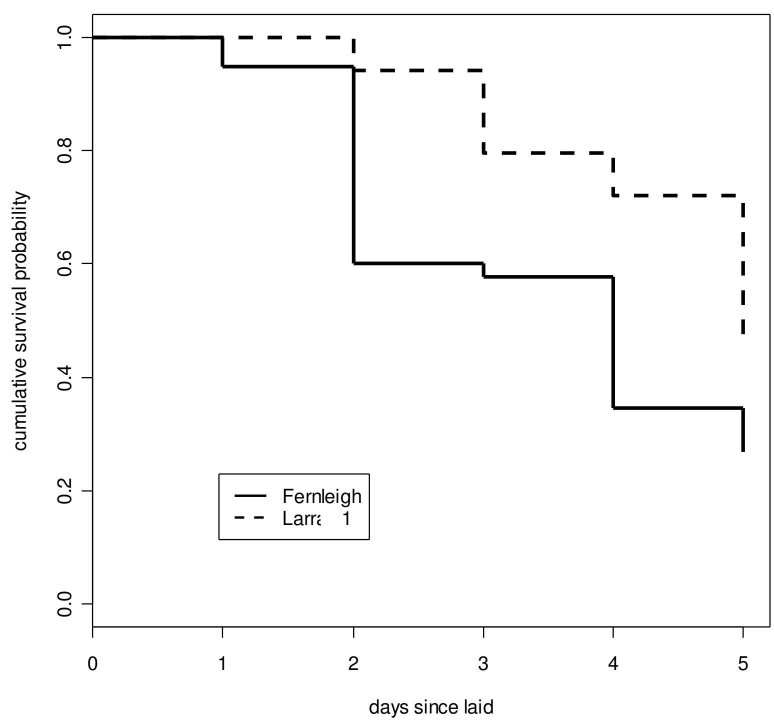

Figure 3.3: Survivorship of the initial baits laid at each site for the non-toxic trials.

3.3.2 Bait caching

Non-toxic

Day-old chickens, chicken wingettes and Foxoff® were used as bait during all trials apart from autumn 2001 trials where no wingettes were tested. In the Fernleigh spring 2002 trial, transmitters were inserted for the entire period. Therefore, the values used for the number of free-feed baits taken from the station during free-feeding were calculated from the number of baits either eaten or cached by foxes.

Figures 3.4, 3.5 and 3.6 show the proportion of baits cached by foxes from those removed for Larras, Fernleigh, and pooled for both sites respectively.

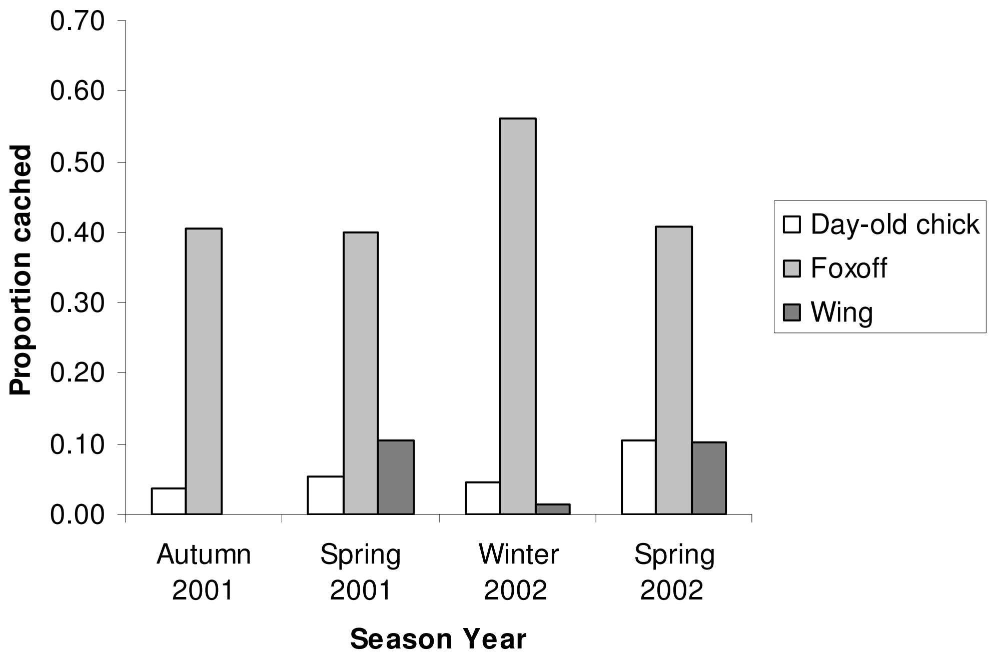

Figure 3.4: The proportion of non-toxic Foxoff®, day-old chick and wingette baits cached from those taken on Larras in the seasons tested.

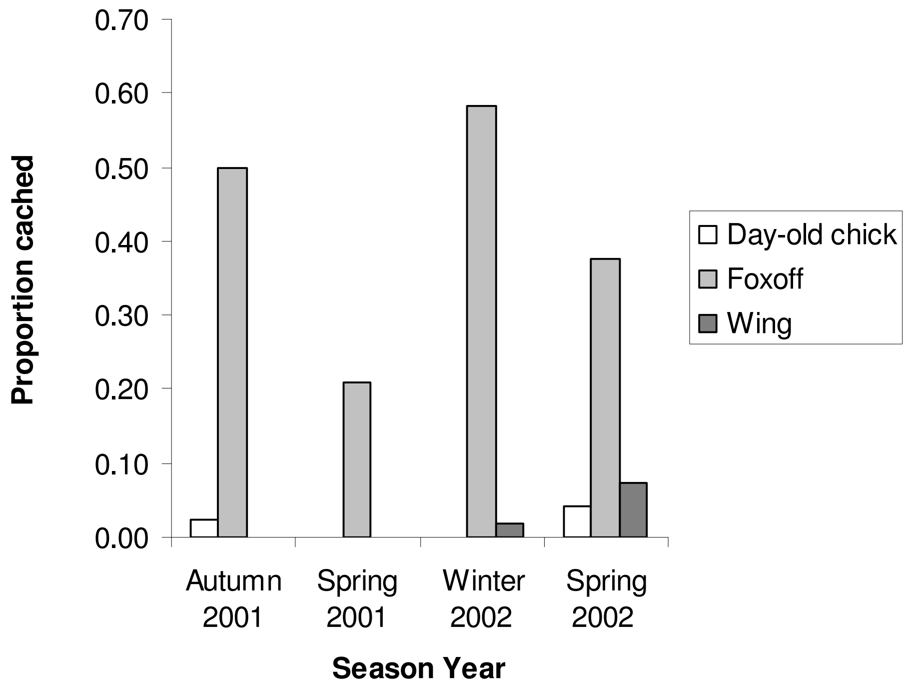

Figure 3.5: The proportion of non-toxic Foxoff®, day-old chick and wingette baits cached from those taken on Fernleigh in the seasons tested.

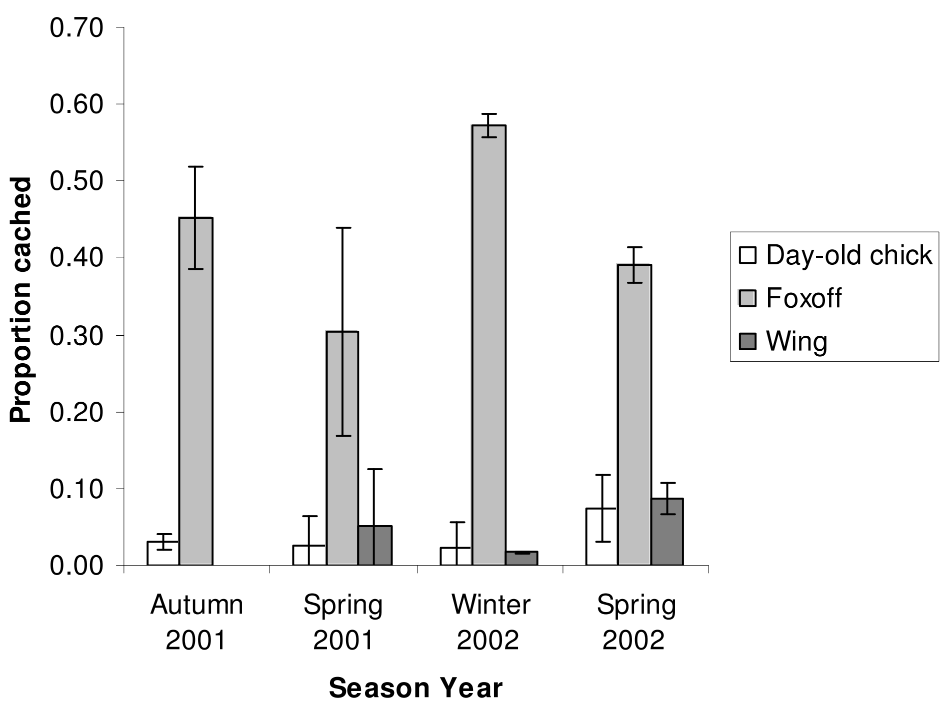

Figure 3.6: The proportion of non-toxic Foxoff®, day-old chick and wingette baits cached from those taken, for data pooled from Fernleigh and Larras in the seasons tested.

At Larras, of the three bait types, a greater proportion of Foxoff® baits were cached when removed by foxes in each season (Fig 3.3). The proportion of Foxoff® baits cached from those taken ranged between 0.40 in spring 2001 (n = 25 baits taken) to 0.56 in winter 2002 (n = 16). A low proportion of both day-old chicks and wingettes were cached during all trials. The proportion of day-old chicks cached from those taken ranged between 0.04 in autumn 2001 (n = 27) and 0.11 in spring 2002 (n = 89). Similarly, a low proportion of wingettes were cached, between 0.01 in winter 2002 (n = 66) and 0.10 in spring 2001 (n = 48).

Similarly, at Fernleigh, a greater proportion of Foxoff® were cached than both wingettes and day-old chicks in all trials in all seasons. The proportion of Foxoff® baits cached from taken baits ranged between 0.21 in spring 2001 (n = 43) to 0.58 in winter 2002 (n = 12). Day-old chicks and wingettes were cached at low levels in all seasons. The proportion of wingettes cached from taken ranged from 0.00 (spring 2001, n = 40) to 0.07 (spring 2002, n = 69). No day-old chicks were cached in spring 2001 (n = 53) and only 0.04 (n = 70) were cached in spring 2002.

When data for both sites was pooled, the mean proportion ($\pm$SD) of Foxoff® baits cached in winter 2002 (0.57 ± 0.01, n = 28) was greater than autumn 2001 (0.45 ± 0.07, n = 60), spring 2001 (0.30 ± 0.13, n = 68), and spring 2002 (0.39 ± 0.02, n = 59). However, a winter peak in caching is not reflected in the proportion of wingettes and day-old chicks cached. A greater proportion of both day-old chicks (0.07 ± 0.04, n = 146) and wingettes (0.08 ± 0.02, n = 158) were cached in spring 2002 than any other season.

Logistic regression revealed that Bait type (χ^2 = 158.19, d.f. = 2, P <0.001) was the principal variable influencing the probability of a bait being cached. Season Year was not significant overall (χ^2 = 6.67, d.f. = 3, P = 0.08), but interacted significantly with Site (χ^2 = 11.26, d.f. = 3, P = 0.01) and the number of baits removed (χ^2 = 12.85, d.f. = 1, P <0.001). No other variables or second-order interactions were significant. As a result, Season Year and Site were analysed within each site to determine seasonal differences.

At Fernleigh, caching was significantly influenced by the Season Year of the trial ($\chi^2 = 15.89$, d.f = 3, P = 0.01), with spring 2001 having less baits cached than autumn 2001 (β = -2.18, z = -3.34, P < 0.001), spring 2002 (β = -1.63, z = -2.57, P = 0.01), and winter 2002 (β = -1.64, z = -3.23, P = 0.001). However, there was no significant interaction between the Season Year and the number of baits removed in the free-feed period ($\chi^2 = 6.36$, d.f = 3, P = 0.10).

At Larras, Season Year did not significantly influence caching ($\chi^2 = 0.25$, d.f = 3, P = 0.97). However, there was a significant interaction between the Season Year and the number of baits removed in the free-feed period ($\chi^2 = 9.46$, d.f = 3, P = 0.02). The number of baits removed from a station in winter 2002 significantly increased the probability of a bait being cached compared to spring 2002 (β = -1.24, z = -2.11, P = 0.04) but not Spring 2001 (β = 0.63, z = 0.76, P = 0.45) or autumn 2001(β = -0.25, z = -0.27, P = 0.79).

Foxoff® were significantly more likely to be cached when taken than day-old chicks (β = 3.07, z = 10.02, P <0.001) and wingettes (β = 2.84, z = 9.2, P <0.001) but there was no significant difference between wingettes and day-old chicks (β = 0.24 , z = 0.70, P = 0.47).

Caching at Larras was significantly greater than at Fernleigh during spring 2001 (β = 2.30, z = 2.02, P = 0.04) but not for any other Season Year.

Toxic

A total of 59 from 129 (45.7%) toxic baits taken by foxes were cached on the two trial sites, Myrangle and Nandillyan. Logistic regression revealed that the factors bait type ($\chi^2 = 18.270$, d.f. = 2, P <0.001) and Site ($\chi^2 = 4.972$, d.f. = 1, P = 0.02) were significant, indicating a significant difference between the sites and the bait types in the probability of a bait being cached. On Nandillyan, a bait had significantly less probability of being cached than at Myrangle (β = -0.9475, z = -2.163, P = 0.0306). When taken by foxes, 26.2% of day-old chicks (n = 42) were cached, compared to 43.1% of wingettes (n = 51) and 74.3% of Foxoff® (n = 35). Foxoff® was more likely to be cached than day-old chicks (β = -2.23, z = -4.085, *P* < 0.001) and wingettes (β = -1.52 , z = -2.994, P = 0.002). The probability of day-old chicks being cached was not significantly different from wingettes (β = -0.71382, z = -1.556, P = 0.1197).

There was no significant difference between winter 2001 and winter 2002 (χ^2 =0.907, d.f. = 1, P = 0.341). Similarly, caching was not significantly influenced by the number of baits removed from each station during the free-feed period (χ^2 =0.501, d.f. = 1, P = 0.479), fox density (χ^2 =0.196, d.f. = 1, P = 0.658) or any second-order interactions.

Figures 3.7 – 3.9 present the proportion of toxic baits cached during winter 2001 and winter 2002 on Myrangle, Fernleigh, and both sites pooled respectively.

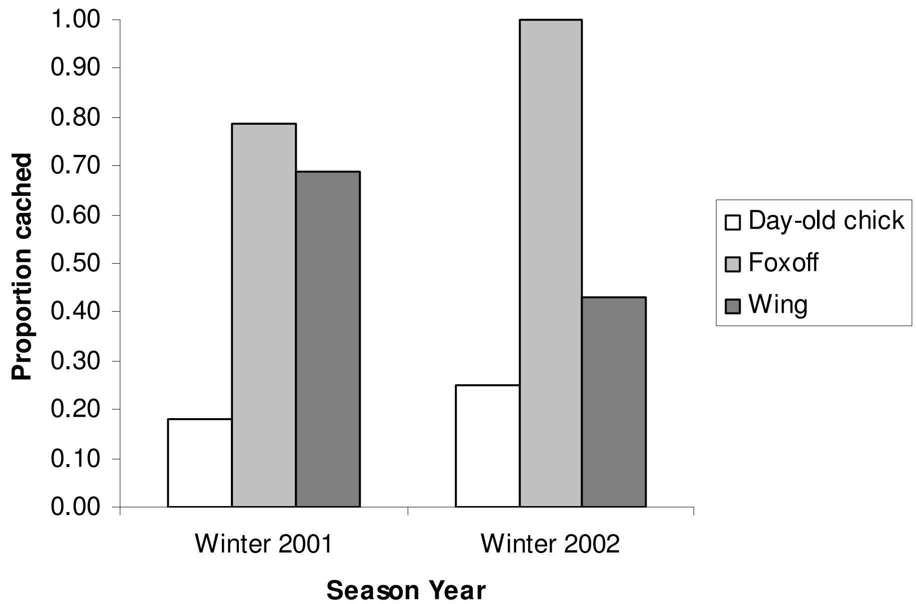

Figure 3.7: The proportion of toxic Foxoff®, day-old chick and wingette baits cached from those taken during winter 2001 and winter 2002 on Myrangle.

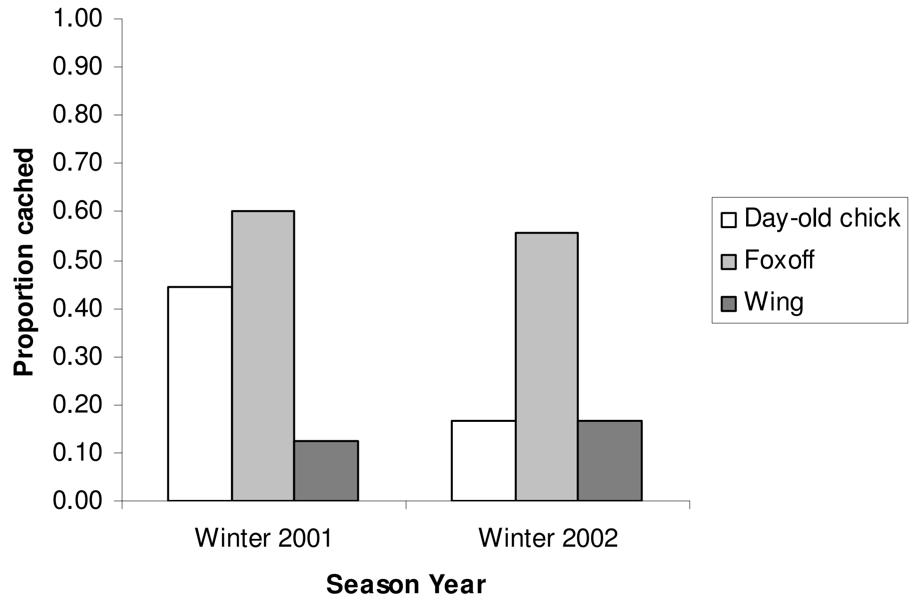

Figure 3.8: The proportion of toxic Foxoff®, day-old chick and wingette baits cached from those taken during winter 2001 and winter 2002 on Nandillyan.

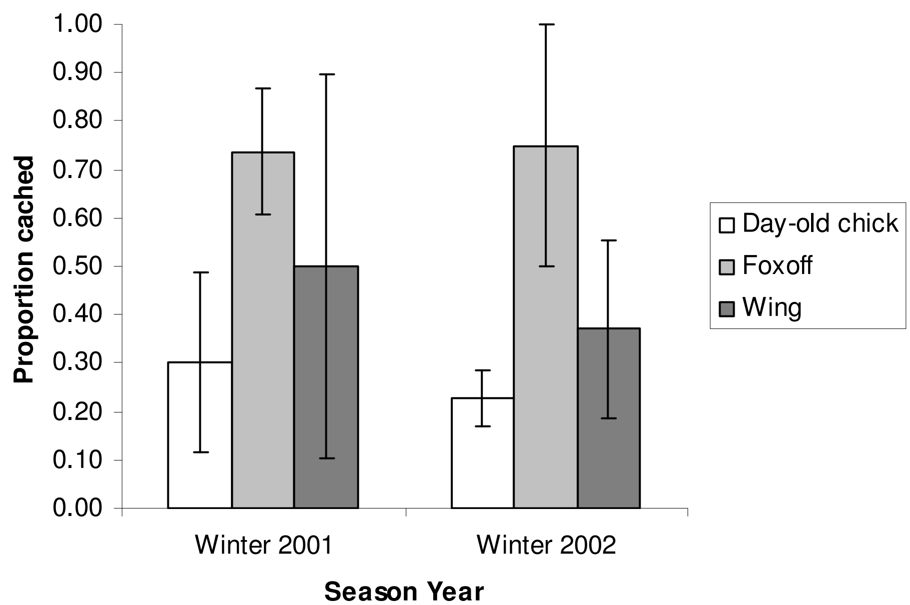

Figure 3.9: The proportion of toxic Foxoff®, day-old chick and wingette baits cached from those taken during winter 2001 and winter 2002 on the trial sites Myrangle and Nandillyan. Error bars indicate standard deviation.

Toxic vs Non-toxic

A comparison between the probability of toxic and non-toxic baits being cached when taken was statistically compared for the trials undertaken during winter 2002. After accounting for differences due to bait type, fox density and the number of baits removed during the free-feed period, poisoned baits on Nandillyan and Myrangle were significantly more likely to be cached than non-toxic baits on Larras and Fernleigh (β =-2.95, z = 5.73, P <0.001).

3.3.2.1 Cache retrieval

A total of 125 cached non-toxic baits were monitored, 73 at Larras and 52 at Fernleigh. The majority were Foxoff® (68 %), followed by wingettes (16.8 %) and day-old chicks (15.2%). Only 13.6% of cached 1080 baits (n = 59) were retrieved in the four 1080 trials. Table 3.3 summarises the retrieval times in days for the cached baits throughout the non-toxic and toxic trials.

Non-toxic

The mean (±SD) number of days that day-old chicks (2.69±1.93, n = 19), Foxoff®, (3.05±2.12, n = 85) and wingettes (3.00±1.91, n = 21) remained cached before consumption by foxes appears to be similar. However, the mean and variance of the survival times (see Table 3.4) are not reliable indicators of the differences between covariates in survival analyses (Crawley 2002).

Table 3.3: The number of Foxoff®, day-old chick and wingette baits eaten from those that were cached in the trials at Larras, Fernleigh, Myrangle and Nandillyan. *No measure of variation (SD) available since only one cache was retrieved.

Site	Season / Year	Bait type	Number cached	Total number of cached baits retrieved	Mean days til eaten (±SD)
Non-toxic					
Fernleigh	Autumn 2001	Foxoff®	14	2	7.75±5.32
Fernleigh*	Autumn 2001	Day-old chick	1	1	3.00
Larras	Autumn 2001	Foxoff®	13	9	2.67±1.80
Larras*	Autumn 2001	Day-old chick	1	1	1.00
Fernleigh	Spring 2001	Foxoff®	9	8	3.00±2.00
Fernleigh	Spring 2001	Day-old chick	0	-	-
Fernleigh	Spring 2001	Wingette	0	-	-
Larras	Spring 2001	Foxoff®	10	7	2.86±2.67
Larras	Spring 2001	Day-old chick	4	2	4.00±1.41
Larras	Spring 2001	Wingette	5	3	2.33±1.53
Fernleigh	Winter 2002	Foxoff®	12	6	3.67±2.88
Fernleigh*	Winter 2002	Day-old chick	3	2	1.00
Fernleigh	Winter 2002	Wingette	5	4	4.50±1.00
Larras	Winter 2002	Foxoff®	11	6	2.67±2.07
Larras	Winter 2002	Day-old chick	8	6	2.67±2.25
Larras	Winter 2002	Wingette	9	5	2.20±2.17
Fernleigh	Spring 2002	Foxoff®	7	3	3.67±1.53
Fernleigh	Spring 2002	Day-old chick	0	-	-
Fernleigh	Spring 2002	Wingette	1	0	-
Larras	Spring 2002	Foxoff®	9	7	3.50±2.12
Larras*	Spring 2002	Day-old chick	2	1	5.00
Larras	Spring 2002	Wingette	1	0	-
1080					
Nandillyan*	Winter 2001	Foxoff®	3	1	5.00
Nandillyan	Winter 2001	Day-old chick	4	0	-
Nandillyan	Winter 2001	Wingette	1	0	-
Myrangle*	Winter 2001	Foxoff®	11	1	4.00
Myrangle	Winter 2001	Day-old chick	2	0	-
Myrangle	Winter 2001	Wingette	11	2	4.5±4.95
Nandillyan	Winter 2002	Foxoff®	5	0	-
Nandillyan*	Winter 2002	Day-old chick	1	1	3.00
Nandillyan	Winter 2002	Wingette	1	0	-
Myrangle	Winter 2002	Foxoff®	7	0	-
Myrangle	Winter 2002	Day-old chick	4	2	3.5±3.53
Myrangle*	Winter 2002	Wingette	9	1	2.00

Table 3.4: The mean number of days that baits were cached before consumption by foxes in the trial periods on Larras and Fernleigh.

Site	Season Year	Number cached	Number eaten	Mean days til eaten (SD)
Fernleigh	Autumn 2001	15	2	3.33 (2.52)
Fernleigh	Spring 2001	9	8	2.78 (1.99)
Fernleigh	Winter 2002	20	12	3.20 (2.95)
Fernleigh	Spring 2002	8	3	5.63 (3.07)
Larras	Autumn 2001	14	10	2.36 (1.55)
Larras	Spring 2001	19	12	3.58 (2.89)
Larras	Winter 2002	28	17	3.04 (2.73)
Larras	Spring 2002	12	3	6.17 (2.89)

Analyses of deviance revealed that the survival time of non-toxic baits was significantly influenced by the Season Year of the trial (χ^2 = 11.94, d.f = 3, P = 0.01) and the distance cached from the station (χ^2 = 5.41, d.f = 1, P = 0.02). The survivorship of the different bait types was not significantly different (χ^2 = 3.41, d.f. = 2, P = 0.18). There was no significant difference between Larras and Fernleigh in the survival time of cached baits (χ^2 = 0.42, d.f = 1, P = 0.52) but the term Site was not removed from the model since the interaction between Site and Season Year was significant (χ^2 = 18.72, d.f. = 3, P = 0.003). The final model took the form:

Survival ~ Site (ns) + Season Year + Season Year:Site + ln (Distance)

As a result, the cumulative survival curves consisting of the baseline hazard function with the estimated survival function for a given Season Year are shown in Figure 3.10. Each survival function represents the mean survival for an average individual bait with average values of the covariates Site and log (distance cached). Each curve is an estimate of individual survival in each stratum with an average Site and log (distance).

The factor Season Year was significant (d.f = 3, χ^2 = 11.94, P = 0.01), indicating that cached baits were retrieved after significantly different periods between seasons. The model coefficients indicate that autumn 2001 (β = -1.821, z = -2.811, P = 0.005) had significantly less hazard (i.e. less likely to be retrieved) compared to winter 2002. Autumn 2001 also showed significantly less hazard than spring 2001 (β = -2.7004, z = -3.833, P = 0.001) but was not significantly different to spring 2002 (z = -1.715, P = 0.086). Spring 2001 (z = 1.776, P = 0.076) and spring 2002 (z = -0.537, P = 0.59) were not significantly different to winter 2002. Similarly, spring 2001 was not significantly different to spring 2002 (β = 1.452, z = 1.72, P = 0.08). This is probably due to the low number of baits retrieved during spring 2002 (n = 6) compared to autumn 2001 (n = 15), spring 2001 (n = 20) and winter 2002 (n = 29).

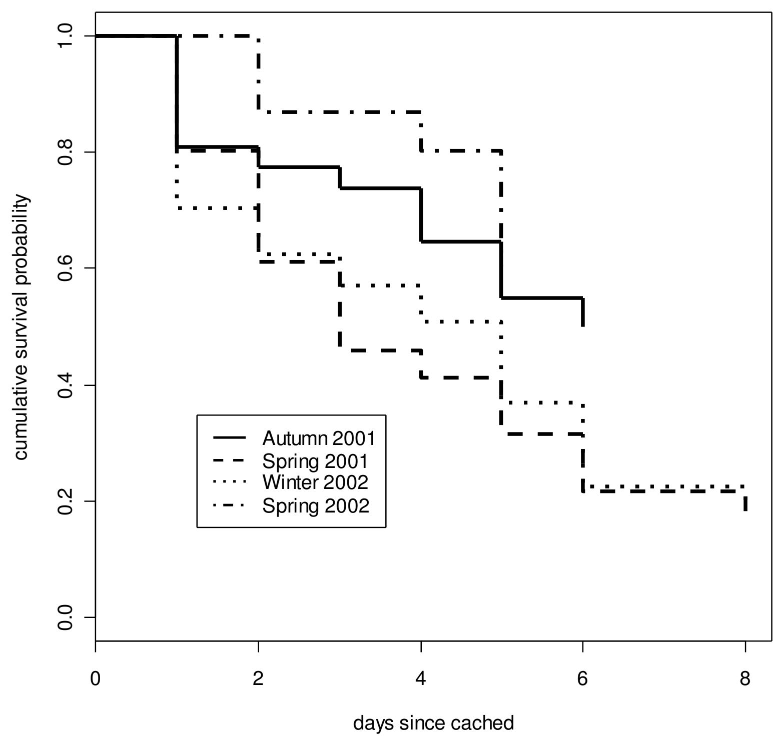

Figure 3.10: Cumulative survival of cached non-toxic baits for the Season Year of trial.

Table 3.5: Number of baits cached, number subsequently eaten, and mean number of days that baits are cached until eaten. Percentage of cached baits subsequently eaten are shown in parentheses.

Season Year	Number of baits cached	Number of cached subsequently eaten (%)	Mean days til eaten $\pm$SD
Autumn 2001	29	13 (44.8)	4.62 $\pm$ 3.23
Spring 2001	28	20 (71.4)	3.32 $\pm$ 2.63
Winter 2002	48	29 (60.4)	3.10 $\pm$ 2.79
Spring 2002	20	6 (30)	5.95 $\pm$ 2.89

Despite that Site was not significantly different overall, the significant interaction between Site and Season Year (d.f. = 3, χ^2 = 18.72, P = 0.003) indicates that baits survived for significantly different rates within the two sites. As a result, the seasonal survival of cached baits was investigated within each site separately.

The model coefficients indicate that at Larras, spring 2002 (β = -1.6045, z = -2.351, P = 0.019), showed significantly greater survival compared to autumn 2001. Both spring 2001 (β = -0.4263, z = -0.972, P = 0.33) and winter 2002 (β = -0.0447, z = -2.829, P = 0.92) were not significantly different to autumn 2001, but winter 2002 had reduced survival times (β = 1.56, z = 2.46, P = 0.0140) compared to spring 2002 but not spring 2001 (z = 1.81, P = 0.071).

At Fernleigh, Spring 2001 survival was significantly less than autumn 2001 (β =2.3471, z = 3.142, P = 0.002) and winter 2002 (β = 1.8905, z = 2.898, P = 0.004), but was not significantly different to spring 2002 (z = 0.906, P = 0.31). Spring 2002 was not significantly different to autumn 2001 (z= -1.013, P = 0.31) and winter 2002 (z= 1.244, P = 0.21) but showed greater survival than spring 2001 (β =1.4294, z = 2.052, P = 0.04). Survival was not significantly different in spring 2001 compared to winter 2002 (z = -0.804, P = 0.42).

The distance to the cache from the bait station was significant, with a negative correlation between the distance cached and survival (β = -0.333, z = -2.082, P = 0.0370).

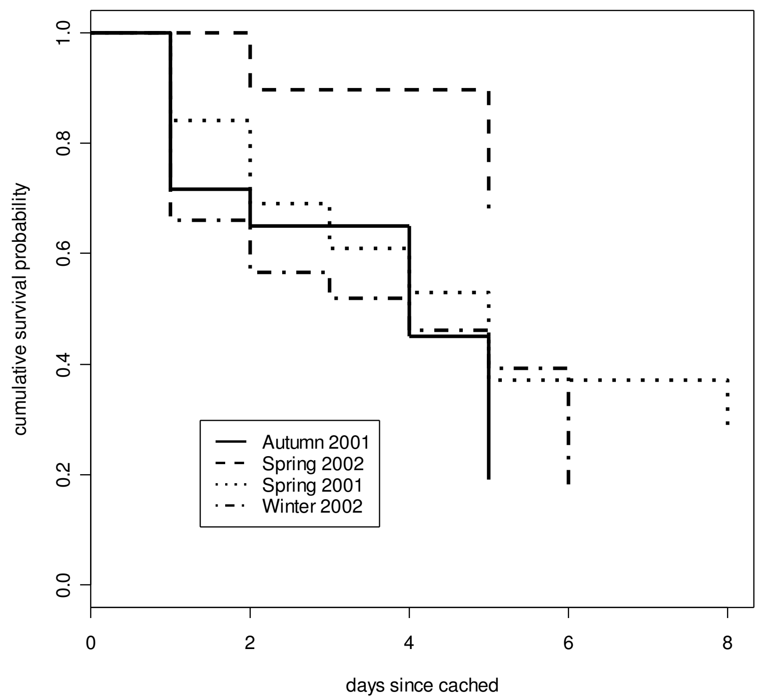

Figure 3.11: Survivorship of cached baits at Larras for the Season Year of the trial.

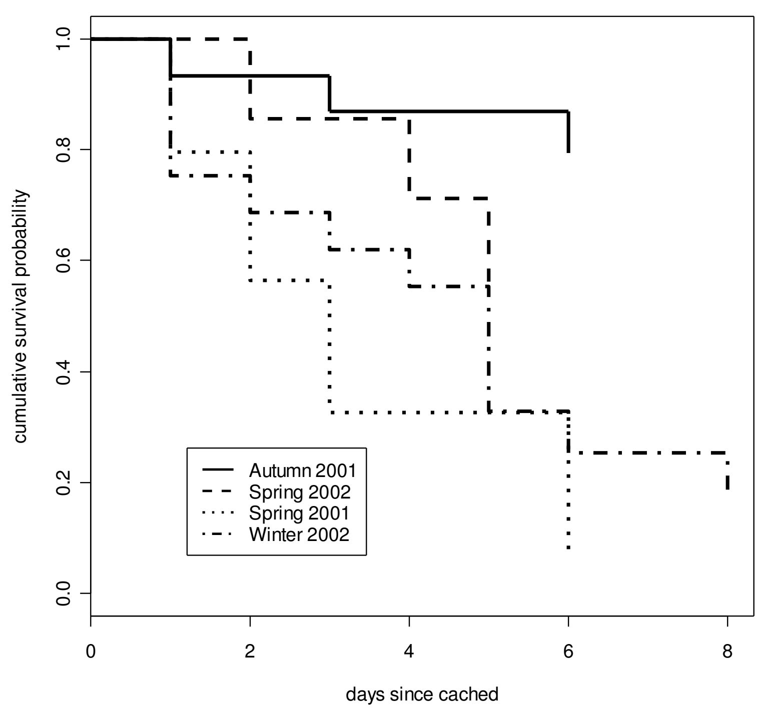

Figure 3.12: Survivorship of cached baits at Fernleigh for the Season Year of the trial.

Toxic

There was no significant difference between the survival rate of toxic cached baits between Season Years (χ^2 = 0.048, d.f. = 1, P = 0.826), Sites (χ^2 = 0.156, d.f. = 1, P = 0.693) or Bait types (χ^2 = 3.33, d.f. =2, P = 0.189). No second order interactions were significant.

Toxic vs. non-toxic

Analyses indicated no difference within the non-toxic and toxic sites in survival of cached baits. Therefore, the two non-toxic and toxic sites were pooled and the survival rates of cached baits were compared for winter 2002. There was a significant difference in the survival rate of cached non-toxic baits than toxic baits (χ^2 = 24.56, d.f. = 1, P < 0.001), with toxic baits having a significantly lower hazard rate (β =-2.176, z = -3.991, P <0.001).

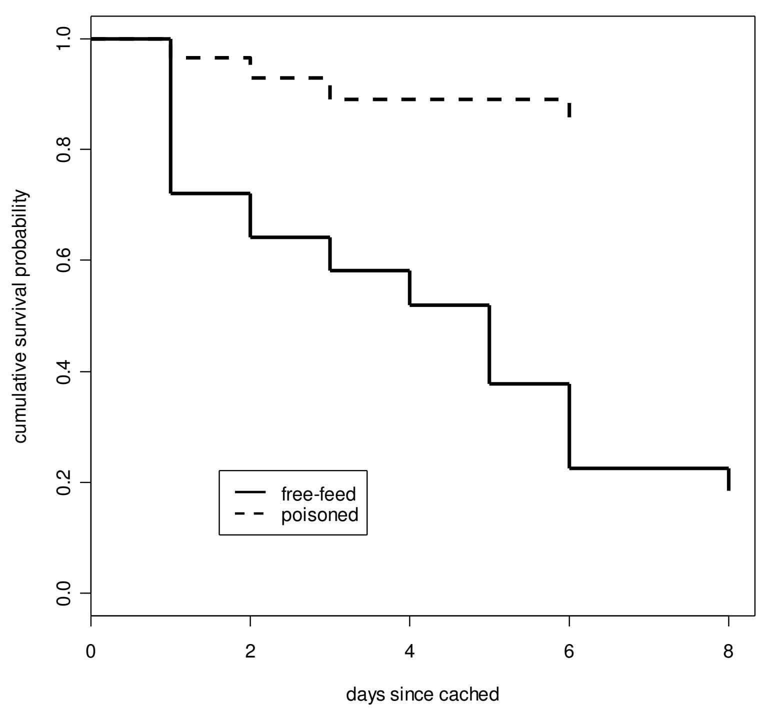

Figure 3.13: Survival of non-toxic (free-feed) and toxic (poisoned) cached baits during winter 2002.

3.3.2.2 Caching distances

Table 3.6 and 3.7 summarise the distances that non-toxic and toxic baits were cached and eaten from stations in each Season Year respectively. Figures 3.12 and 3.13 show the distances that non-toxic and toxic baits are cached and eaten from stations. The mean distance bait was cached from the bait station was 135.9 m, and the median was 90 m. Only 27% of cached baits were located within 100 m of the bait station, 55% were less than 200 m, and 68% were less than 300 m. Those transmitters with the baits eaten from them were located significantly closer (F = 123.95, P <0.001, d.f. = 1) to the bait station than those that were cached, with a mean of 48.0 m and a median of 9 m.

A linear model to determine if the distance that the non-toxic baits were cached was significantly different for the season year of the trial, site, and bait type was undertaken. The distance that bait was taken to be cached was not normally distributed and was subsequently log transformed. Stepwise linear regression revealed that Season Year and number of baits removed by a fox during the free-feed period significantly influenced the distance a bait was cached from the station (F = 7.2753, P = 0.008, d.f. = 1). There was no significant difference in the caching distances of bait types (F = 0.5092, P = 0.602, d.f. = 2). The number of baits removed by a fox in the free-feed period was positively correlated with the distance that baits were cached (β = 0.17888, t = 3.338, P = 0.001). Season Year was also significant (F = 5.2478, P = 0.001, d.f. = 3). Caching distances in autumn 2001 were not significantly different to spring 2001 (t = -0.408, P= 0.68) or winter 2002 (t = -1.112, P = 0.268) but were significantly less than spring 2002 (β = 0.91528, t = 3.436, P<0.001). Baits were also cached at significantly greater distances in spring 2002 than spring 2001 (β = -1.01568, t = -3.742, P<0.001) and winter 2002 (β = -1.1957, t = -4.1414, P <0.001).

There was no significant difference between the caching distances of non-toxic or toxic bait (χ^2 = 1.152, d.f. = 1, P = 0.233) during winter 2002.

Table 3.6: Summary of distances (m) for non-toxic baits cached or eaten. Cached baits are those that are cached when taken from the bait station, eaten are those that are eaten after being taken from the bait station.

	Cached				Eaten			
Season Year	Mean (SD)	Median	Range	N	Mean (SD)	Median	Range	N
Autumn 2001	99.0 (87.9)	65	19 – 340	29	26.8 (44.9)	12	0.1 – 249	100
Spring 2001	127.2 (136.6)	74	3 – 575	28	59.0 (128.7)	8.5	0.1 – 843	252
Winter 2002	112.5 (82.4)	90	14 – 880	48	27.4 (63.4)	5	0.1 – 604	205
Spring 2002	264.3 (235.0)	207	9 - 338	19	76.2 (150.2)	16	0.1 - 1300	312
Overall	135.9	90	3 - 880	124	48.0	9	0.1 - 1300	869

Table 3.7: Summary of distances (m) that toxic baits were cached or eaten. Cached baits are those that are cached when taken from the bait station, eaten are those that are eaten after being taken from the bait station.

	Cached				Eaten			
Season Year	Mean (SD)	Median	Range	N	Mean (SD)	Median	Range	N
Winter 2001	78.2 (85.6)	102	0.5-279	32	58.0 (92.6)	27	0.5-445	30 (total 31)
Winter 2002	104.0 (92.2)	86	5-398	27	55.9 (76.0)	34	0.1-289	35 (total 38)
Overall	90.0 (88.8)	57	0.5-398	59	56.8 (83.4)	27	0.1-445	65 (69)

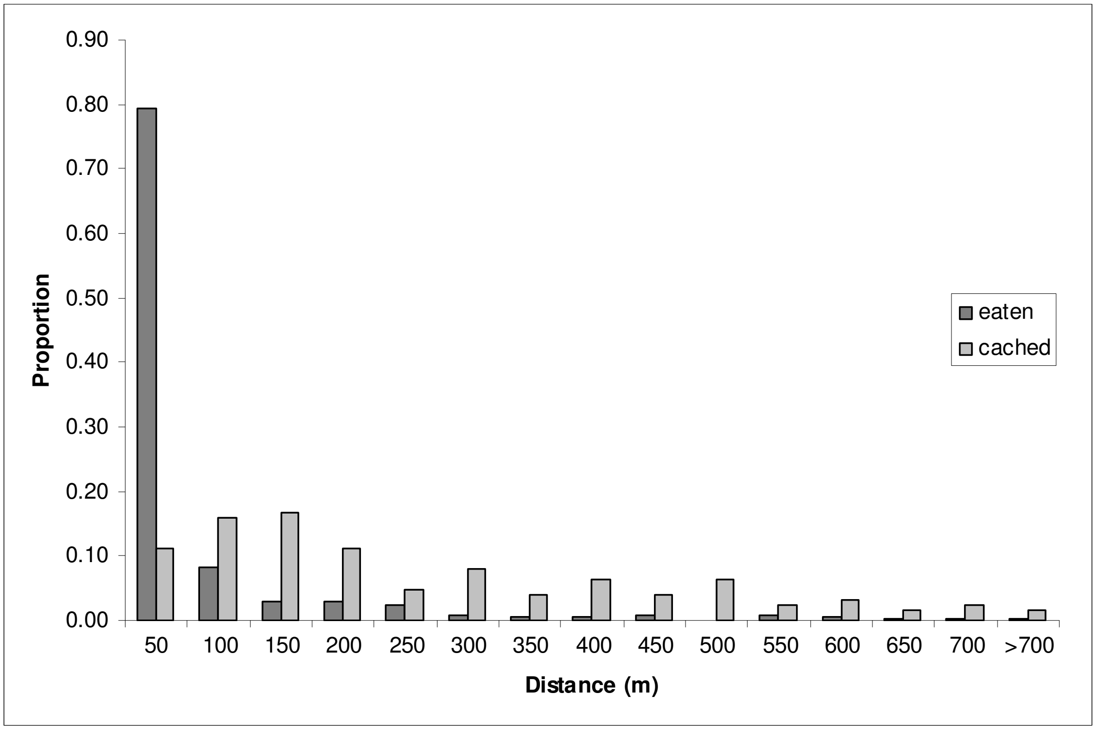

Figure 3.14: The distance from the bait stations that non-toxic baits were eaten (n = 869) or cached (n = 124).

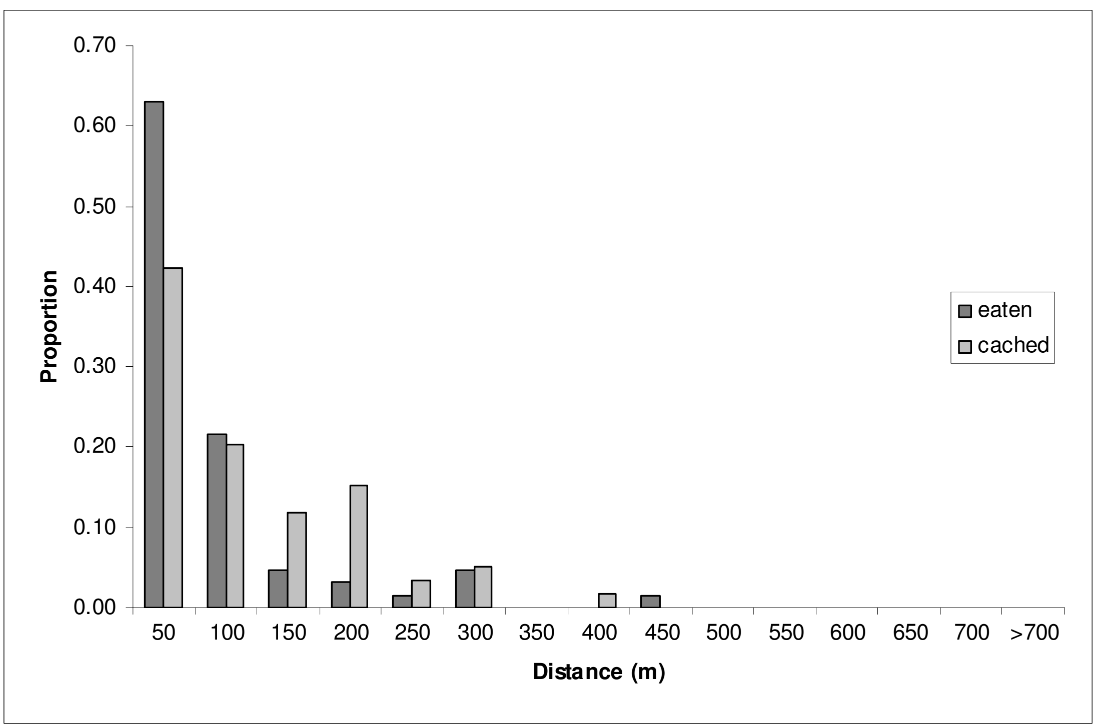

Figure 3.15: The distance from the bait stations that toxic baits were eaten (n = 65) or cached (n = 59).

3.3.2.3 Cache depth

Of the baits that were cached, 65.2% were buried (n = 184) and covered with between 0 and 120 mm of soil (median of 10 mm, mean ($\pm$SD) = 18.1$\pm$23.2 mm).

A linear model was used to determine if the depth that the non-toxic bait was cached was significantly different for Season Year, Site, and Bait type. The depth that baits were cached was not normally distributed and was subsequently log transformed. There was no significant difference in the caching depths for the bait types (F = 0.5092, P = 0.602, d.f. = 2), for any Season Year (F = 0.7463, P = 0.5278, d.f. = 3) or between Sites (F = 0.5868, P = 0.4460, d.f. = 1).

3.3.2.4 Free-feeding and caching

The number of baits removed by foxes or unknown species in the free-feed period from a station was positively correlated with the probability of a non-toxic bait being cached during winter 2002 (β = 0.513, z = 3.319, P = 0.009). The relationship was not significant during the other seasons, nor for toxic baits (χ^2 = 0.501, d.f. = 1, P = 0.479). Wingettes showed a significant increase in the probability of being cached with increasing number of free-feed taken, (β = 2.214, z = 2.557, P = 0.010); Foxoff® (β = 0.411, z = 1.851, P = 0.064) and day-old chicks (β = 0.334, z = 0.834, P = 0.404) showed some indication of increasing probability of being cached, but were not significant.

3.4 Discussion

Bait caching may be detrimental to the efficacy, safety and cost-effectiveness of poisoning programs. Greater understanding of the influences of caching will assist in developing strategies to minimise the effect of caching on control programs. The results indicate that caching intensity varied considerably depending on the bait type, the season of presentation and whether the bait contained 1080. The manufactured Foxoff® bait was cached significantly more than the two fresh chicken baits in every season, but caching intensity peaked during winter 2002, probably as a result of a combination of its low palatability and high availability of alternative food to foraging foxes. 1080 baits appear to be less palatable to foxes than non-toxic baits which has serious implications for fox baiting programs.

3.4.1 Bait uptake

Bait type did not significantly influence the uptake of baits initially presented at bait stations and there was no consistent seasonal influence on bait uptake for both sites. At each site the survival of the non-toxic baits was significantly influenced by the Season Year of the trial, both Larras and Fernleigh showing a general increase in the total percentage of baits removed from the initial to the final trial, with the exception of spring 2002 at Fernleigh (72.2%) which declined from winter 2002 (85%). Additionally the survival of baits was negatively correlated with fox density, with greatest survival when fox density was relatively low.

These relationships probably reflect associative animal learning, or contagion (Thorpe 1963; Thompson and Fleming 1994). Presenting non-toxic bait at the same site at three month or greater intervals could lead to resident foxes becoming habituated to the presence of baits and hence the rate of bait uptake would increase. Similarly, daily bait replacement encourages revisitation by individual foxes. The survival analyses used to investigate bait uptake, therefore, only included the initial baits placed at each bait station in an attempt to reduce bias associated with learning within each trial. The results indicate that it is likely that learning, both within each trial period and between trial periods may have contributed to increased uptake of the initial baits laid. This major confounding factor seriously affects the interpretation of these analyses for practical implications for fox baiting programs, and should be used with caution.

These findings are supported by other field studies investigating bait uptake. Although not commented upon, the results of Trewhella *et al.* (1991) strongly suggest a similar relationship when investigating seasonal bait uptake by urban foxes in Bristol. Bait uptake rates were measured at the same sites (stations) at two-monthly intervals; the results indicated a gradual increase in the overall bait uptake rate throughout the year. Therefore the rate of bait uptake cited by Trewhella *et al.* (1991), calculated from when bait take asymptotes, is confounded by the prior visitation of foxes to that station. Studies investigating the uptake of attractant and flavour-enhanced baits in the United Kingdom found some evidence of learning by resident foxes (J. Woods and G. Smith, Central Science Laboratory, pers. comm. 2003). In the current study, the difference between bait survival between sites indicates that site differences (e.g.

food abundance) or behavioural differences (e.g. foraging activity) may confound the ability to assess overall seasonal influences on bait uptake. This study demonstrates that to adequately assess seasonal changes in bait uptake, trials should be undertaken on both permanent and single-use sites, replicated over many years, to account for confounding by revisitation and differences between fox populations and sites.

3.4.2 Bait caching

The probability that non-toxic bait would be eaten or cached when taken was significantly influenced by the type of bait and the number of baits removed from that station in the free-feed period. There was also a significant interaction between the Site and Season Year, indicating that seasonal changes in the probability of bait being cached were significant within sites, but there were no trends consistent on both sites for all bait types.

The probability that bait would be eaten or cached when taken was strongly influenced by bait type. Foxoff® were cached significantly more in both non-toxic and 1080 trials. In the non-toxic trials, a total of 66.9% of Foxoff® compared to 5.7% wingette and 4.5% day-old chick baits were cached when taken by foxes. The toxic trials showed an even higher rate of caching; an average of 74.3% of Foxoff® were cached compared to 43.1% wingette and 26.2% of day-old chick baits. Results from semi-tame or captive foxes indicate that caching is related to the palatability of the bait substrate, with preferred baits eaten more frequently cached less often (Macdonald 1977; Van Polanen Petel *et al.* 2001). Therefore the results from this study indicate that Foxoff® are less palatable than day-old chicks and wingettes, and that toxic baits are less palatable than non-toxic baits.

Previous studies have shown Foxoff® to be relatively unpalatable when compared to other bait types. Van Polanen Petel *et al.* (2001) tested the caching of deep fried liver (DFL), dried deep fried liver (DDFL) and Foxoff®. DFL was preferentially eaten, followed by DDFL and then Foxoff®.

The results indicate that 1080 baits are significantly more likely to be cached, and less likely to be retrieved than non-toxic baits. Consumption of toxic bait would have resulted in an individual dying and thus unable to cache any subsequent bait, unless these baits were encountered in the latent period before any poisoning symptoms appeared. Symptoms usually appear between 30 minutes and 4 hours following consumption of toxic bait (Chenowith and Gilman 1946; Egekeze and Oehme 1979; Sheehan 1984; Staples *et al.* 1995; Marks *et al.* 2000); foxes may encounter and potentially cache multiple baits within this period. In the non-toxic field trials, exposed transmitters (i.e. indicating consumed bait) were occasionally found adjacent to freshly dug holes or depressions, suggesting that they were caches that had been made earlier in the night before being retrieved. In the toxic trials, these individuals may die before being able to retrieve their caches, leaving many caches intact. Since foxes usually do not locate another foxes cache (Macdonald 1976, 1977), toxic caches would be more likely to remain intact after the death of the responsible individual, especially over the relatively short period that caches were monitored.

1080 is reportedly tasteless and odourless when used in 3 mg concentrations added to bait (Sheehan 1984). There is some evidence from conditioned taste aversion field trials that foxes can detect bait that is injected with levamisole, a tasteless and odourless chemical (see Chapter 4). These baits appeared to be avoided following previous consumption of levamisole treated bait. Aversion to 1080 has been reported in other species such as brushtail possums (*Trichosurus vulpecular*) (O'Connor and Mathews 1999) usually as the result of non-lethal bait consumption. Such aversion mechanisms are probably not responsible here; there was no 1080 baiting undertaken on both field sites for at least two years prior to the initial trial in 2001. Additionally, all caches were retrieved before periods when they were likely to contain sub-lethal doses, so foxes wouldn't have had the opportunity to consume a sub-lethal dose. Lastly, there was no difference in proportions of baits cached between the 2001 and 2002 trials, indicating that the initial trial did not result in a bait averse population.

It is possible that 1080 is detectable and its addition into bait reduces the palatability of the bait. All baits used to assess caching in the 1080 and non-toxic trials were handled in the same manner; transmitters were inserted in all baits using the same techniques. The only difference was the addition of 1080; the fresh chicken baits were injected with 1080 solution, while Foxoff® were commercially manufactured to contain 1080. 1080 is known to reduce the palatability of bait to brush-tail possums, dunnarts (*Sminthopsis* spp.) and some rodents (Morgan 1982; Sinclair and Bird 1984; Calver *et al.* 1989) and may be responsible for the increased caching of 1080 baits by foxes. Free-feeding may have promoted caching of the toxic baits. Free-feeding would have habituated foxes to the taste of non-toxic bait; the subsequent inclusion of 1080 may have prompted a neophobic reaction, reducing the bait palatability and increasing the likelihood of being cached. It is difficult to determine whether the increased caching of 1080 relative to non-toxic bait is a result of a low overall palatability of 1080 bait, a reduction in 'same-night' retrievals, or a combination of both. Regardless, the fact that a lower proportion of 1080 baits are consumed should be investigated further since it has implications for the efficiency and safety of fox baiting campaigns.

The percentage of non-toxic Foxoff® cached peaked during winter 2002 on both sites, with 56% and 58% of those taken cached on Larras and Fernleigh respectively. This may be related to either nutritional or behavioural changes relating to fox reproduction. A study assessing the seasonal fat deposition and body composition of foxes in central-west New South Wales (Winstanley *et al.* 1999) concluded the greatest decline in body condition occurred during the peak whelping and cub-raising period (August to November). The greatest decline in condition for females was during September, which coincides with the peak in whelping (McIlroy *et al.* 2001). Body fat declined in males during the mating period (July) reflecting the energy demands of defending a breeding territory (Winstanley *et al.* 1999). This may reflect the reduction in foraging; males may be so busy defining and defending their territory and searching for mating opportunities that foraging becomes a secondary concern (Saunders and McLeod In Press). Alternatively, the reduction in body fat may reflect low food availability. Therefore, a decline in body condition means that energy demands are not met by dietary intake, which may be caused by either low food availability or foxes foraging less and relying on energy reserves to meet demand. The winter 2002 caching trials were undertaken in July, when male body condition is declining while female body condition is peaking. If males are reducing their foraging activity during this period, then the peak in Foxoff® cached during this period is probably a result of the overabundance of food available to females during this period. This is supported by some findings in the literature. Caching behaviour is closely linked to food ingestion (Vander Wall 1990), which is regulated at two levels, short and long term. Short term regulation occurs as a result of satiation following feeding, longer term it is affected by the individual's nutritional status. As a result, satiation responds to local conditions of food availability, whereas the latter is a function of nutritional deficit or obesity (Herberg and Blundell 1967; Herberg and Blundell 1970; Vander Wall 1990; Rice-Oxley 1993).

Fox density is at its lowest during winter since the annual whelping period only commences in later August/early September (McIlroy *et al.* 2001). Since the number of baits available was more or less constant during each trial, each individual would have an increased number of baits available to it during this period.

The fact that the winter peak in caching is not reflected in the proportions of the two chicken bait types cached, may be explained through interpreting some observations recorded during the trials. Observations whilst recovering or monitoring transmitter baits during both toxic and non-toxic trials suggest that foxes can access multiple baits within the one night. On several occasions during the non-toxic trials up to three transmitters were found within a few metres of one another, suggesting that a single fox was responsible for removing at least three baits within the one night. Foxes have been reported to consume food until satiated, after which point any subsequent food located is cached for later consumption (Henry 1986). Additionally, foxes may cache less-preferred prey, returning only if more-preferred prey is not available or satiation is not reached (Macdonald 1977). Therefore, if individual foxes removed multiple baits, and consumed the more palatable types until satiated, the less palatable bait types would be more likely to remain cached. This may be the reason for the peak in caching of Foxoff® during winter, when fox density is lowest, since the more preferred baits encountered (chicken wingettes and day-old chicks) would be consumed until satiation, after which the 'excess' baits would remain cached.

Alternatively, the apparent increase in caching activity during winter may be due to foxes storing food in preparation for the whelping/cub-raising period (Macdonald 1977) where energy demands are greatest (Winstanley *et al.* 1999). This is unlikely since the retrieval of caches during this period was not significantly different to the other trial periods.

Additionally, long-term storage in caches is probably restricted to very cold climates where spoilage is reduced (Macdonald *et al.* 1994).

The reduced caching of Foxoff® in both spring 2001 and spring 2002 also coincides with the period of peak energy demand in foxes (August-November) (Winstanley *et al.* 1999) suggesting that bait would be more readily taken during these periods. Additionally, the winter peak in caching of Foxoff® was not reflected in the other bait types, with less than 1% of day-old chicks and 2% of wingettes cached during this period respectively. The lack of consistent seasonal peaks in caching for all bait types suggests that there may be some seasonal change in dietary preference driven by complex behavioural and physiological changes influencing the response of foxes to different food types.

There was a significant interaction between Season Year and the number of baits removed from a station before inclusion of transmitters. Similarly, the number of baits removed from a station before the inclusion of transmitters had no significant effect on caching. The interaction indicates that the continual replacement of free-feed bait in a station significantly increased caching only during winter 2002. Since caching is a response to an overabundance of food (Vander Wall 1990) it is possible that continual replacement of non-toxic bait may promote caching. However, in autumn 2001, bait was significantly less likely to be cached with an increase in the number of baits taken from a station. Therefore, an alternative hypothesis may be that continual replacement of baits reduces caching, since foxes become habituated to the presence of food, and 'switch' to consuming bait. However, the relationship between bait replacement and increased consumption was generally negative for all trials but only significant for the autumn 2001 trial. There is no obvious explanation why this occurred during the autumn 2001 trials and not the other trial periods, but should be investigated further.

There were significant site differences in caching, with significantly more baits cached at Larras than at Fernleigh. This was probably just due to differences in fox behaviour at both sites. Although food availability was not measured on both sites, the sites were within the same region, had similar levels of fox density (as evidenced by the spotlight abundance indices) and would have received similar amounts of rainfall. Since the density of foxes is positively correlated with the productivity of the country (Saunders *et al.* 1995), the abundance of food was probably similar on the two sites. However, this would not explain any short-term changes in food abundance likely to have occurred on these properties due to differences in management, e.g. stocking levels throughout this period.

3.4.2.1 Cache retrieval

Foxes are generally scatter hoarders with caches only usually containing one prey item. Foxes are thought to relocate caches by remembering the precise location of each cache site through spatial and/or visual cues (Macdonald 1976, 1987). Foxes usually retrieve caches by directly approaching the cache site (Murie 1936; Scott 1943) and, when caches are moved a short distance from the original cache site, foxes will rarely recover them (Macdonald 1987). This suggests that caches should be retrieved only by the animals that are responsible for making that cache, or through observations of animals that make that cache (Jeselnik and Brisbin 1980; Macdonald 1987; Vander Wall 1990).

Macdonald (1976) found that caches containing more preferred prey are retrieved earlier than those containing less preferred prey. It is therefore surprising that there was no significant difference in the retrieval rates of the cached bait types, particularly with the marked differences in bait palatability between Foxoff® and the two chicken bait types. Additionally, if foods with a greater potential for spoilage are probably retrieved at a faster rate (Vander Wall 1990) then you would expect that day-old chicks and wingettes should be retrieved earlier. This suggests that fresh bait types may be resistant to caching as a function of their greater potential for spoilage (see Chapter 2), while Foxoff® may be prone to caching as a result of its greater shelf life. However this study could not account for the order that individual foxes retrieved baits, only the retrieval rates of all the caches could be compared. Individuals may not have accessed or cached all bait types, and then would not have been able to retrieve caches in order of preference. Additionally, the large variation in retrieval times of all baits, and the small sample size of the cached fresh bait types made comparisons difficult.

Despite that a high proportion of Foxoff® taken were cached in this study, many caches were retrieved. Overall, 58.4% of non-toxic baits cached were retrieved within four days. This contrasts with some other studies that report that foxes and other canids usually recover meat within one day (Murie 1936; Scott 1943). This retrieval rate appears similar to other studies (Saunders *et al.* 1999; Thomson and Kok 2002) where 78% and 80% of non-toxic baits (Foxoff® and dried meat respectively) were retrieved within ten days. However, due to the need to conserve transmitter life, all caches had to be retrieved at the end of a ten-day trial period; therefore not all caches could be monitored for uniform periods. Despite this, it appears that foxes will retrieve and consume the majority of non-toxic caches.

The probability of a cache being retrieved was influenced by the Season Year of the trial (Figure 3.9). Retrieval of caches in spring 2002 was generally less than that in other trials but this was inconsistent between the two sites. On Larras, the probability of a cache being retrieved was less during the spring 2002 trial than all other trials apart from the one undertaken in spring 2001. Baits cached during spring 2002 at Fernleigh remained cached for significantly longer periods than all other seasons tested apart from autumn 2001.

The abnormal environmental conditions during mid to late 2002 may be partly responsible. A severe drought occurred on the central tablelands during this period (evidenced by cumulative rainfall deficiency: Figure 3.1), which produced a higher than normal mortality of domestic stock, including spring-born lambs (S. Brown, Larras Lake North, pers. comm. 2002). This higher than normal mortality of stock would have resulted in elevated levels of carrion being available to foxes. Since caching is directly related to food abundance, elevated food abundance may have resulted in increased caching during this period. During this period, bait uptake during the free-feed period was generally greater than during other trial periods. This result was, therefore, probably due to the abnormal seasonal conditions than any true behavioural shift.

3.4.2.2 Caching distances

There was no difference between the cache distances of toxic and non-toxic baits, nor between bait types. The mean distance baits were cached was 135.9 m, with 55% caches located less than 200 m and 68% less than 300 m, with a maximum of 880 m from the original location. This is greater than that found by Thomson and Kok (2002) in Western Australia (86.9 m) where 58% of cached baits were found within 50 m. Distances were comparable with studies in similar habitats in eastern Australia where the mean distances were 156 m and 112 m /126 m respectively (Saunders *et al.* 1999; Van Polanen Petel *et al.* 2001).

These results provide evidence consistent with previous studies (Saunders *et al.* 1999; Van Polanen Petel *et al.* 2001; Thomson and Kok 2002) that baits may be cached at considerable distances from their original location. However, non-toxic baits were cached at greater distances during spring 2002 (mean = 264.3 m) than all other trial periods (Table 4.6). Mean distance during spring 2001 also appeared greater (127.2 m) than during either autumn 2001 (99.0 m) or winter 2002 (112.5 m), although this was not significant. The apparent Spring peak in caching distance was also noted by Thomson and Kok (2002) and is probably due to foxes caching baits closer to dens to provision cubs (Macdonald 1977; Macdonald *et al.* 1994). The harsh seasonal conditions during spring 2002 may have increased the area foraged by individuals, resulting in greater movement of caches closer to den sites or areas secure from other foxes. If caching distances during spring campaigns are consistently greater than other periods, then baiting during this period may offer greater potential risk to non-target species through moving baits onto areas thought to be bait free.

3.4.2.3 Cache depth

The majority of cached baits in this study were buried (65.2%), with a median of 10 mm (range 1-120 mm) of soil covering the bait. This supports other studies that found that burial depths range from shallow depressions such as 10 mm (Saunders *et al.* 1999; Thomson and Kok 2002) to 70-100 mm (Henry 1986). Baits that were not buried were usually well concealed and hidden under leaf or grass litter, under shrubs, grass tussocks or other vegetation but some were simply dropped on to the surface. Cache sites were typically located in open habitats, with no common distinguishing features to characterise their location. Given that cache sites are typically well hidden (Murie 1936; Kruuk 1964; Macdonald 1976; Henry 1986; Saunders *et al.* 1999; Thomson and Kok 2002) and appear to be usually retrieved only by the fox that made the cache (Macdonald 1976), it is probable that few cached baits would be retrieved by other animals. This would especially be the case for the study area where there are few non-target animals present that are capable of removing and consuming bait (see Section 1.8 and 8.2). Additionally, the 1080 in baits usually degrades rapidly under field conditions, allowing only a finite period where cached baits would constitute a significant non-target threat (see Chapter 2). However, Kortner *et al.* (2003) suggested that one spotted-tailed quoll (*Dasyurus maculatus*) may have died following the consumption of cached 1080 bait 5-6 weeks after the completion of a fox baiting campaign. Clearly cached baits do present some risk to individual non-target animals, but the level of risk is probably low.

3.4.2.4 Free-feeding and caching

Free-feeding a bait station appears to encourage caching. Additionally, the number of baits removed from a station during the free-feed period was positively correlated with the distance that baits were cached. This suggests that prolonged free-feeding may not only result in an increased incidence of caching, but the resultant caches may be located further from the original location. As discussed above, free-feeding may reduce the palatability of 1080 baits through habituation to the taste of non-toxic bait before presentation of the different, possibly less palatable bait. Although not significant across all trial periods, free-feeding also appears to encourage caching of identical successive baits presented. Continual replacement of non-toxic baits in a particular location would habituate foxes to a readily available, replenishable food source. Depending on the environmental food availability and relative palatability of the food (bait) presented, this habituation may encourage foxes to either consume or cache these baits. Either way, free-feeding encourages re-visitation by individual foxes resulting in an increase in the number of baits available to each fox and hence, increase in the number of baits required for a baiting campaign. As a result, such strategies may reduce the efficiency of baiting practices.

3.4.3 Management implications

This study provides some important results that should be considered to improve the safety and efficiency of baiting campaigns.

The results from the bait uptake and caching trials highlight the importance of assessing the fate of baits after being taken rather than just bait uptake. Studies investigating palatability through bait uptake should be assessed with caution since uptake may not be directly correlated with bait palatability. For example, field trials based on bait uptake found that Foxoff® and DK-9 (both manufactured baits) were the most acceptable, followed by chicken heads, meat (mutton), and various types of offal (P. Fleming, NSW Agriculture unpublished data). How this uptake of each bait type relates to consumption is unknown. An excellent example of the discrepancy between bait uptake and consumption is presented by Kortner *et al.* (2003) where 19 from 20 Foxoff® removed by spotted-tailed quolls (*Dasyurus maculatus*) were found uneaten a short distance from the bait station. This indicates that although baits may be removed, it does not provide a good indication of the palatability of bait. Experiments that are undertaken to assess the palatability of bait should use transmitters or other means (e.g. tracking spool) to assess whether removed baits are consumed, or misleading results may be obtained.

The low palatability of 1080 bait relative to non-toxic bait may have serious efficiency and safety implications for current fox control campaigns. If foxes can detect and avoid 1080, then baiting programs would be less efficient than if a less detectable toxin is used. If foxes are caching multiple 1080 baits before succumbing to bait, then these baits will be unable to be located and retrieved by the operator at the completion of the campaign.

If experiments on bait uptake and consumption are undertaken using non-toxic bait and the results applied to 1080 baiting campaigns, the palatability of baits may be significantly overestimated. For example, experiments using biomarkers in a non-toxic matrix to simulate the proportion of the population susceptible to 1080 baiting (e.g. Murray *et al.* 2000) may significantly overestimate this proportion through presenting relatively more palatable bait.

Results from these experiments should be recognised as potential overestimates and subsequently treated with caution.

Baits appear to be cached at greater distances during spring; additionally, those baits cached at greater distances are less likely to be retrieved, so the risk may be compounded during spring campaigns. Therefore, extra caution should be applied during spring campaigns to avoid farm dogs consuming bait. Strategies such as placing bait stations at further distances from property boundaries, or neighbouring landholders imposing a larger 'buffer zone' where domestic dogs are excluded should be considered to reduce the potential for poisoning.

The common practice of free-feeding in conservation areas to assess which animals are visiting and removing bait from bait stations may be increasing the likelihood of caching by foxes, especially if baiting is undertaken with less palatable bait types. Foxoff® is often used in conservation areas since it is has a long-shelf life and is easy to handle and prepare (see Chapter 5). It is also relatively unpalatable to some non-target species (Kortner *et al.* 2003). Free-feeding may be a good measure to assess which animals are visiting a bait station, but it may act to put non-target species at risk through increasing the proportion of baits that are cached and not retrieved at the end of the campaign.

One of the most important findings of this study is that caching may be reduced in any season by presenting a highly palatable bait type. The results indicate that wingettes and day-old chicks offer a significant advantage of reduced caching relative to Foxoff®. Using a highly palatable bait type such as chicken wingettes or day-old chicks will ensure that a high proportion of those taken by foxes are eaten, and fewer will be cached and remain cached at unknown locations where they cannot be retrieved. This will minimise the risk to domestic pets and other non-target species from consuming cached baits. However, other issues, such as bait longevity and cost-effectiveness are important considerations in deciding which bait type to use.

3.5 Conclusion

The results from the caching trials show that considerable proportions of baits removed by foxes may be cached. Bait caching may be detrimental to the effectiveness and efficiency of baiting campaigns and have implications for non-target safety. Since the intensity of the caching is largely dependent upon the palatability of the bait, presenting highly palatable bait would be one strategy to reduce caching, and hence, caching associated problems. This implies that wingette and day-old chick bait would be more suitable for fox management than Foxoff®. However, other considerations, such as bait longevity (Chapter 2), handling, and cost-effectiveness may be equally or more important, and need to be considered when choosing an appropriate bait type.