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Investigation into the use of bait stations for the control of the European wild rabbit (Oryctolagus Cuniculus) in the urban bushland reserve of Bold Park, Perth, Western Australia

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Investigation into the use of bait stations for the control of the European wild rabbit (*Oryctolagus cuniculus*) in the urban bushland reserve of Bold Park, Perth, Western Australia.

by

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ABSTRACT

European rabbits in Australia have a significant impact on the environment and the economy. It is therefore necessary to implement control programs. In rural areas a number of methods including warren ripping and poisoning are frequently used. In urban areas though, rabbit control is not as easily accomplished because the use of many control methods is not appropriate. For example, the poison 1080 often cannot be used due to public health concerns and warren ripping cannot be used in conservation areas. Poisoning with pindone, an anticoagulant, is therefore one of few options available to the managers of urban reserves. However, the use of pindone is not without risks to wildlife and domestic animals.

This study was conducted in Bold Park, Perth, Western Australia, as it was recognised that rabbits have a tremendous impact on the bushland. The study investigated the use of bait stations during a baiting program and was designed to: assess the bait uptake from two different bait station designs; identify animals visiting the bait stations; and determine whether these animals showed a preference for one of the bait station designs. Prior to the field trials, oat seed viability studies were carried out to ensure that the oat seeds used as bait would not germinate in the field. To identify animals visiting the bait stations (through tracks and scats), bait stations were placed onto existing sand plots. The study showed that rabbits accepted bait stations and fed from both bait station types. Although they preferred the slab design the difference in visitation was not significant. Bird visitation to the drum design was significantly lower than to the slab design and rodents visited the drum more often than the slab design. From these results it was concluded that bait stations similar to the drum design should be used whenever bird poisoning is a concern. When small native mammals are present in the area, additional precautions should be taken to protect these animals from being poisoned. Also discussed are potential problems associated with the use of bait stations.

DECLARATION

I certify that this thesis does not, to the best of my knowledge and belief:

(i) incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher degrees;

(ii) contain any material previously published or written by another person except where due reference is made in the text; or

(iii) contain any defamatory material.

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1. INTRODUCTION

Since the settlement of Australia by Europeans, at least 72 vertebrate and 500 invertebrate species have been introduced into Australia (Burgman & Lindenmayer, 1998). Some of these species were able to reproduce and establish wild populations. Following naturalisation, many of the introduced species have had an effect on native flora and fauna. However, very little is known about their ecological characteristics (Burgman & Lindenmayer, 1998). Only the few introduced species that pose a severe threat to the Australian environment and economy, such as the rabbit and the fox, have been studied in more detail (e.g. Myers & Poole, 1963; Myers *et al.*, 1975; Williams *et al.*, 1995; Twigg *et al.*, 1998b; Moriarty *et al.*, 2000; Jackson, 2003).

European rabbits in Australia are a significant environmental and economical problem (e.g. Williams *et al.* 1995). They affect on the regeneration of vegetation, the composition of plant communities and ultimately destroy native vegetation. Such destruction ultimately increases the risk of soil erosion and weed invasion (e.g. Williams *et al.*, 1995; Bridle & Kirkpatrick, 2001; Gillman & Ogden, 2003). Rabbits also have direct and indirect effects on the native fauna (e.g. Robley *et al.*, 2002). They compete for resources such as food and burrows and they destroy vegetation which is necessary for the survival of native fauna. Economical effects include reduced crop yields, reduced stock carrying capacity of the land, costs for rabbit control and costs for the revegetation of land (e.g. Myers & Poole, 1963; Williams *et al.*, 1995). Due to their affects on the environment and the economy, rabbits have been identified as a serious pest in the legislation of all Australian states and territories (Williams *et al.*, 1995).

In the past, most research in rabbit control was concentrated in rural areas to protect bush remnants and farms. More recently, the conservation value of urban bushlands has become more important to humans and more and more research has been undertaken in urban settings (Williams *et al.*, 1995). However, rabbit control in urban areas is not as easily accomplished as in

rural areas due to public concerns about health and welfare (Robinson *et al.*, 1990; Twigg, 2001).

One of the largest urban bushlands on the Swan Coastal Plain is Bold Park (Botanic Garden and Parks Authority (BGPA), 2000). The current vision for Bold Park is to "be identified as a world-class urban wilderness enjoyed, studied and managed with the community" (BGPA, 2000). Recently it has been noted that rabbits have had a tremendous effect on the regeneration and revegetation of Bold Park. It has therefore been recognised that pest control is necessary (Buist, 2004). Buist (2004) identified that poisoning with pindone is the most appropriate control method. However, the risk to non-target animals needed to be investigated before a poisoning program could be implemented. This study investigated whether bait stations could be used in Bold Park to minimise the affect on non-target animals without compromising the efficacy of a baiting program.

1.1. Rabbits in Australia

1.1.1. The introduction of rabbits to Australia

All wild rabbits found in Australia belong to the same species: the European wild rabbit, *Oryctolagus cuniculus* (e.g. Myers *et al.*, 1989; Williams *et al.*, 1995). The European rabbit originated in Spain and was transported by traders and sailors to many parts of the world, where they were used as game and as a food source. They were also released on islands as a food source for sailors (e.g. Rolls, 1969; Myers *et al.*, 1989).

The first rabbits to reach Australia came with the First Fleet in 1788 and the first feral populations were recorded in south-eastern Tasmania. In some areas of Tasmania, rabbits were able to establish large populations and by 1827 some of these populations consisted of thousands of rabbits (e.g. Sheail, 1971; Williams *et al.*, 1995). The first successful introduction of wild rabbits to the mainland occurred in 1859, when twenty-four wild rabbits from England were brought to an estate in Geelong, Victoria (e.g. Rolls, 1969; Hinds *et al.*, 1996). They were housed in enclosures but some either escaped or were set free soon after they arrived. From Geelong, and a second introduction point in South Australia, the rabbits first spread relatively slowly. After approximately 15 years, the rate of dispersal increased, but was dependant on the vegetation type and weather conditions. In wet woodlands rabbits colonised land at about 10-15 km per year, while in the rangelands the dispersal rate reached over 100 km per year (e.g. Myers *et al.*, 1989; Williams *et al.*, 1995). By 1900, rabbits had spread over most of southern Australia and by 1980 they were found in all areas except the very north of Western Australia, the Northern Territory and Queensland (Figure 1.1, Williams *et al.*, 1995).

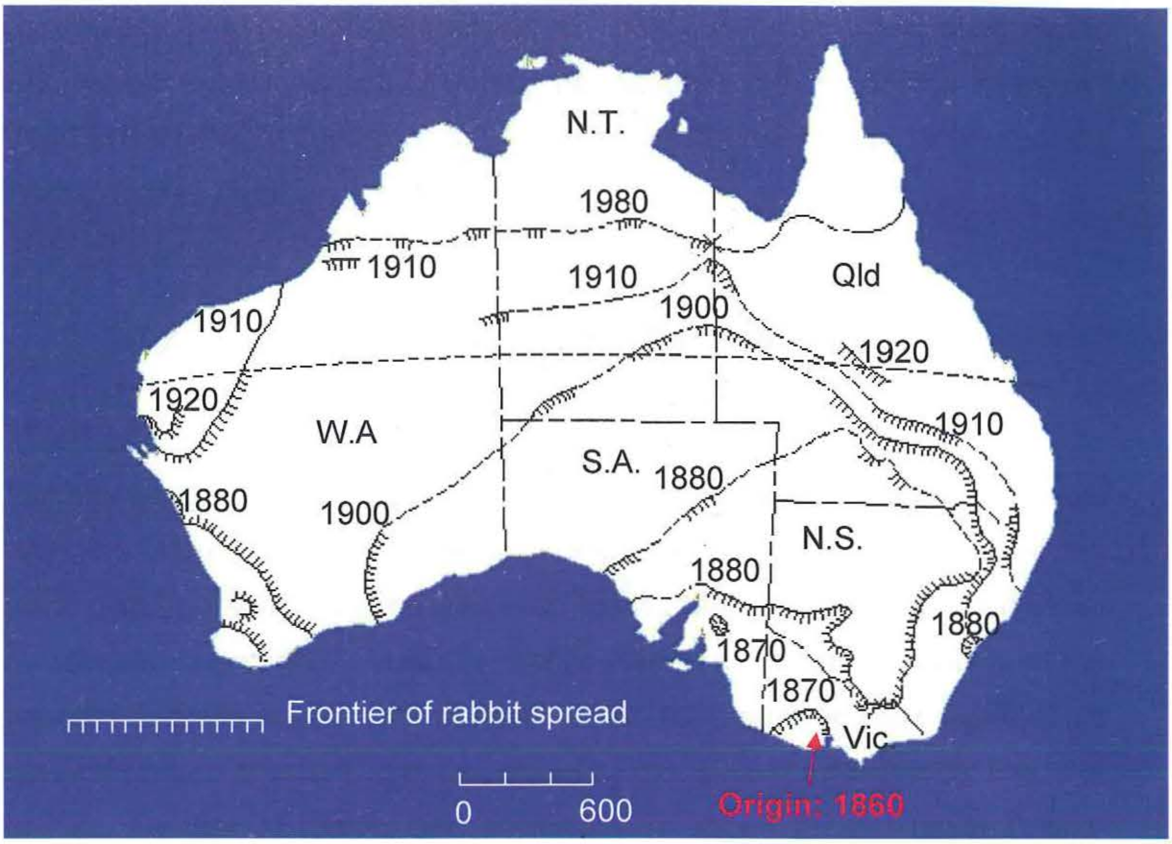

Figure 1.1 Map of Australia showing the expanding range of the European rabbit (*Oryctolagus cuniculus*) after its introduction into Australia in 1959. After Hinds *et al.*, 1996.

To prevent rabbits from colonising all of Australia fences, such as the rabbit proof fence in Western Australia, were erected (Williams *et al.*, 1995). Despite these efforts rabbits had colonised about four million km^2 within 60 years (Myers, 1995). The fast rate of dispersal in Australia, the fastest of any feral mammal, was made possible through the aid of humans (Williams *et al.*, 1995). Humans altered the landscape making it more suitable for rabbits and provided abundant and nutritious food by introducing European annual grasses and winter crops (Sheail, 1971; Williams *et al.*, 1995).

Currently rabbits occur in most vegetation types throughout southern Australia (e.g. Parer & Libke, 1985; Williams *et al.*, 1995). The only areas that are not readily colonised are black soil plains, dense forests and altitudes above 1500 m. In areas with dense cover rabbits mainly live on the surface, using shallow depressions (squats) under vegetation and logs and some small warrens. In open areas the use of large warrens is preferred, however, squats are utilised if available (e.g. Parer & Libke, 1985; Williams *et al.*1995). In contrast to southern Australia, the distribution of rabbits in northern

Australia is very patchy (Williams *et al.*, 1995) and only areas surrounding man-made waterholes are colonised permanently (Myers, 1995). However, despite the harsher conditions in northern Australia rabbits are slowly moving north (Myers, 1995).

1.1.2. The ecology of the rabbit in Australia

Habit

Rabbits usually emerge from their shelter a few hours before sunset to graze near the warrens (e.g. Myers *et al.*, 1989; Williams *et al.*, 1995). After the initial grazing period they socialise near the warren and unless disturbed they remain above ground. At dusk the rabbits start to move further away from the warren to graze again until sunrise, when they seek shelter again. This general pattern of activity can be altered by the level of disturbance, predator activity, number of rabbits and availability of above ground cover (Vitale, 1989; Myers *et al.*, 1989).

The home range of rabbits can vary depending on food availability, sex, age, number of rabbits and availability of above ground cover (Parer, 1982). However, the centre of activity is the warren, with more biomass consumed in the immediate vicinity of the warren than further away. This trend is also observed when bait is placed around warrens (Cowan *et al.*, 1987; Williams *et al.*1995).

Diet

Rabbits prefer green grasses and herbs (Myers, 1995). They select the most nutritious components of plants and are also able to dig into the soil to reach roots and seeds. This selectivity in food can lead to changes in the plant community. During the drier parts of the year rabbits also eat leaves and roots of shrubs as well as bark. They obtain most of their moisture from their food and are only seen drinking water if this is not sufficient (Myers, 1995; Williams *et al.*, 1995).

Social organisation

Rabbits usually live in small social groups that can vary from one male and one female to three males and seven females (e.g. Sheail, 1971; Williams *et al.*, 1995). Each social group is led by a dominant and aggressive male and female. The dominant male usually defends the territory and fights for access to females, while females fight for access to warrens (e.g. Myers, 1995, Williams *et al.*1995). Despite the social system and the territorial behaviour, several social groups often live together within one large warren. However, when rabbit densities are low, one social group may use several warrens (e.g. Wood, 1980; Williams *et al.*1995). Depending on the female dispersal pattern in different areas, rabbits may mate for life, have a different partner every year or be part of polygamous harems (Roberts, 1987).

Reproduction and dispersal

Rabbits are sexually mature at around three to four months (Twigg *et al.*, 1998a). Males can be in breeding condition for most of the year. However, breeding usually correlates with high rainfall and the subsequent high levels of green food (e.g. Rolls, 1969; Sheail, 1971; Twigg *et al.*, 1998a). When the conditions are favourable, a female rabbit can have five or more litters per year, producing 35 or more kittens. In drier conditions a female produces between one and two litters a year, and no more than 11 kittens (Williams *et al.*, 1995). The litter size depends on the age and nutrition of the female as well as the season and is usually between four and seven (Myers, 1995) but can be as high as nine (Twigg *et al.*, 1998a). The mortality rate for rabbits under three months is very high at around 80%. The mortality rate for rabbits above this age decreases and animals between two and three years of age are the most common in a given population (Myers, 1995). Rabbits can live up to seven years but in natural populations only a few reach the age of six (Myers *et al.*, 1989).

Natural control of population size

The population size of rabbits depends on the weather pattern, the vegetation conditions and the time of year (e.g. Myers *et al.*, 1989; Myers, 1995, Williams *et al.*, 1995). During droughts, most populations severely decline or even collapse but after sufficient rain populations can increase dramatically. However, due to rabbit control programs (see section 1.3) excessively large numbers are usually only found where control is not mandatory or its implementation is not controlled or is difficult (e.g. Myers, 1995; Williams *et al.*, 1995; Twigg, 1998a). Populations also exhibit an annual cycle. Numbers are usually lowest just before the breeding season in late summer but can increase by a factor of 2 – 5 at the end of the breeding season (Myers, 1995, Williams *et al.*1995).

Parasites, predators and diseases also play a major part in population size control (Williams *et al.*, 1995). Predation and myxomatosis (see section 1.3) can effectively control the population size in areas with Mediterranean climates. Also, in wetter years, infestation with endoparasites increases, which in turn has a negative effect on the reproduction rate (Williams *et al.*, 1995). In drier areas predation and myxomatosis can be effective, however, rabbits are prolific breeders and will breed whenever conditions are favourable (e.g. Myers, 1995). These reproductive times may not coincide with predator levels and myxomatosis, and thus the population size can increase very rapidly. The main predators of rabbits are the fox (*Vulpes vulpes*) and the feral cat (*Felis catus*), while dingoes (*Canis familiaris dingo*) are important on a local scale (e.g. Parer, 1977; Newsome *et al.*, 1989). Predator removal experiments in Australia have shown that rabbit numbers can increase dramatically when foxes and cats are removed (e.g. Newsome *et al.*, 1989). However, when a rabbit population reaches high density, control by predators can be insufficient (Williams *et al.*, 1995).

1.2. Economical and ecological impacts of rabbits

It is well known that rabbits have an impact on both the economy and the environment (e.g. Johnston, 1969; Norman, 1988; Ingleby, 1991; Williams *et al.*, 1995; Burgman and Lindenmayer, 1998) but according to Williams *et al.* (1995) the available measurements should be used with caution as most of them are derived from anecdotal evidence or experiments without proper controls. Nonetheless, it cannot be denied that rabbits are affecting the environment and the economy in Australia.

Economical impacts

Since European rabbits became well established in Australia they caused great economic losses. Even today, with programs controlling rabbit numbers (see section 1.3), economic losses are estimated at $600 million per year (Department of Agriculture (DoA), 2003). Included in this estimate are the costs of rabbit control programs and research, loss of income due to reduced stock production because of grazing pressure, loss of income due to rabbit grazing on crops and the cost associated with the production, planting and protection of tree seedlings on plantations and in revegetation areas.

Environmental impacts

Impacts of rabbits on the environment are mainly due to the destruction of one type of vegetation and the creation of another. For example, a study by Lange & Graham (1983) found that rabbits in the arid zone were able to prevent the regeneration of *Acacia*s even though rabbit numbers were low (0.5 ha^{-1}). If rabbits graze the recruited seedlings, there will be no *Acacia*s to replace the senescing adults, leading to local extinction of *Acacia*s. Similar patterns have been found for many other plants (e.g. Johnston, 1969; Chesterfield & Parson, 1985; Cooke, 1987; Williams *et al.* 1995).

The effect of rabbit grazing on grasslands has also been profound. In many areas it is believed that numerous grass species have been lost due to rabbit grazing and that subsequently the grassland vegetation consists of species that can withstand the grazing pressure (e.g. Leigh *et al.*, 1989, Foran *et al.*,

1985). In central Australia, for example, Foran *et al.* (1985) showed that the abundance of the native grass *Enneapogon* decreased when rabbits were in moderate abundance.

With the suppression of plant regeneration and growth, the land can become prone to soil erosion, particularly during drought (Williams *et al.*, 1995). These effects have been particularly apparent when rabbits were introduced onto islands (e.g. McManus, 1979; Norman, 1988). For example, the damage caused by rabbits on Rabbit Island has resulted in 20 % of the island being bare and prone to wind erosion. After the eradication of the rabbits it was possible to revegetate this area and soil erosion was reduced to a minimum (Norman, 1988).

The changes in vegetation patterns can also have a flow-on impact on native animals (Williams *et al.*, 1995). The Eyrean grasswren (*Amytornis goyderi*) from South Australia depends on canegrass and in areas where rabbits destroy this type of habitat the population size of these birds is reduced (Parker, 1980). Similar affects have also been found for other birds (e.g. Frith, 1962; Reid & Fleming, 1992).

Direct grazing competition can also have a great impact on native animals. It is believed for example, that yellow-footed rock wallabies (*Petrogale xanthopus*) and spectacled hare-wallabies in Australia are directly competing with rabbits for food (e.g. Ingleby, 1991; Dawson & Ellis, 1979). Particularly during drought events, native animal species are not able to compete with rabbits (Williams *et al.*, 1995). Rabbits are also able to rapidly increase their population size, much faster than any native mammal. Rabbits then disperse, covering large distances and populating the landscape after a drought event. As native animals, particularly small mammals, do not have large dispersal rates, their range decreases over time (Williams *et al.*, 1995).

High rabbit numbers also support large numbers of predators such as foxes, cats and birds of prey and it has been believed that this increases the predation pressure on native animals (e.g. Newsome *et al.*, 1997). In more recent times however, research has shown that the population sizes of small

mammals do not decrease due to increased predation after rabbit numbers decrease (Edwards *et al.*, 2002).

Due to their tremendous environmental and economic impact the need for rabbit control is recognised in the legislation of all Australian states and territories (Williams *et al.*, 1995). Rabbits in Western Australia are declared pests under the Western Australian *Agriculture and Related Resources Protection Act 1976* and warrant control where invasions are identified (Williams *et al.*, 1995; DoA, 2003).

1.3. Control of rabbits

The tremendous impacts of rabbits on the environment and economy early in the history of colonisation in Australia did not go unnoticed and the first *Rabbit Destruction Act* was put into place in 1875 in South Australia (Williams *et al.*, 1995). A variety of methods including shooting, trapping and poisoning with a variety of poisons have been employed since rabbit control was first implemented (e.g. Williams *et al.*, 1995; DoA, 2001a).

Currently, several methods are being used to control rabbit populations (Williams *et al.*, 1995; DoA, 2001a). However, none of these methods are appropriate in every given situation. Furthermore, rabbit control needs to be ongoing as the rabbit problem cannot be solved by a one-off treatment as it is very likely that not all rabbits are eradicated and/or that rabbits from neighbouring warrens recolonise controlled area. Current rabbit control does not rely on one method alone as this is usually not effective enough both in the short- and in the long-term. Instead, current rabbit control usually employs several methods such as warren ripping, warren fumigation and poisoning, applied over time depending on the local situation (see below, Williams *et al.*, 1995).

Warren fumigation

Warren fumigation involves the introduction of poisonous gas into a rabbit warren (DoA, 2000a). Currently there are two methods used: a) static and b) pressure fumigation. Static fumigation involves the use of fumigant tablets, which release phosphine. These tablets are placed into warren entries, which are then sealed with soil. Pressure fumigation involves forcing the emission gas from a car exhaust down a warren (Agriculture Protection Board of WA (APB), 1988b; DoA, 2000a). Both methods are very labour intensive, as all warren entrances need to be found and sealed to achieve successful rabbit control (DOA, 2001a).

Warren fumigation is most effective as a follow-up to poisoning and warren ripping (see below), where small populations persist in isolated areas, and where warren ripping and poisoning are not feasible. However, it is not effective when most rabbits live above ground in dense understorey. If warren fumigation is used, the most effective time to do so is in late summer and/or before planting (APB, 1988b; DoA, 2000a).

Warren destruction

Warren ripping usually involves the clearing of vegetation using heavy equipment such as hydraulic tractor mounted rippers or ploughs. Rips have to be placed at right angles and the soil should be compacted after ripping. This method is very expensive and is not advisable in conservation areas, as large proportions of vegetation are destroyed and soil erosion and weed invasion are likely to occur (DoA, 2000b ; DoA, 2001a).

Another method to destroy rabbit warrens involves the use of explosives. This method is less destructive and can be used in areas that are hard to access with heavy machinery or where ripping would cause soil erosion and/or inflict severe damage to conservation areas. Two methods are recognised for being feasible to destroy rabbit warrens: a) inserting charges into warren entries and b) inserting charges into holes dug across the warren. The latter method is preferred, as more tunnels collapse (DoA, 2002a).

Fencing

Rabbit proof fences around remnant bushlands, which may provide refuge for rabbits, are mostly used in agricultural areas to protect pastures. The bushland remnants in agricultural areas are often located on sandy ridges, which are prone to wind erosion, or near protected road reserves and have intrinsic conservation value. The clearing of these remnants is therefore not an alternative for rabbit control (DoA, 2002b).

When a rabbit-proof fence is erected to protect pastures from rabbit grazing, all rabbits inside the fence need to be removed. Even if low numbers of rabbits remain within the fence, rabbit grazing can adversely affect the bushland. The preferred method of removing rabbits from inside the fence is to use the poison 1080 (see below). If rabbits still remain within the bushland a regular poisoning program needs to be implemented, which would make the erection of the fence a useless and costly exercise (DoA, 2002b; Lowe *et al.*, 2003).

The initial costs for fencing a bushland remnant are high and include the fence itself, labour, and costs for the eradication of rabbits. However, the money saved by being able to protect crops and/or greenstock usually out weighs the initial costs within a reasonable time. Also, a fence, which only needs regular check-ups for breaches, lasts for at least 15 years and tax benefits are available for landholders (DoA, 2002b).

One negative issue associated with fencing of remnant bushlands is that the movement of other animals, such as wallabies and kangaroos, is also restricted (Lowe *et al.*, 2003). The occurrence of any species under threat or of high conservation value and the impact of the fence on these species need to be investigated before a decision about erecting a fence is made (Lowe *et al.*, 2003).

Biological control

Biological control is the use of parasites, diseases and predators instead of chemicals to control weeds and pests (Lawrence, 1995). Biological control of the rabbit in Australia is achieved through the myxoma virus and the rabbit calicivirus. Both viruses have been deliberately introduced to Australia to control the number of wild rabbits.

Myxoma virus

The myxoma virus was imported into Australia in the 1930's to investigate its use as a tool for rabbit control (APB, n.d.) but the first field trials were not very successful. Only after a successful outbreak of the disease in 1950 in south-eastern Australia, was the virus deliberately introduced into wild populations (APB, n.d.; Williams *et al.*, 1995).

Initially the virus had a mortality rate of 95 – 99 % but this has decreased to anywhere between 30 – 90% and is usually around 50%. This is due to three major factors: a) less virulent strains have evolved; b) rabbits have become resistant to the virus; and c) rabbits can acquire short-term and life-long immunity (APB, n.d.; Williams *et al.*, 1995; DoA, 2003).

Lifelong immunity to the virus is acquired when an infected rabbit survives the disease. The rabbit then has antibodies which, if the rabbit becomes infected again, can be activated to fight a new infection. The immunity can also be passed on from females to kittens by passing on antibodies from female to kitten during pregnancy. This kind of immunity only lasts for about two to three months, as the kittens do not have the ability to produce antibodies themselves. However, if the kittens become infected with the virus during this time, they usually survive and acquire lifelong immunity. Due to lifelong and short-term immunity of rabbits an outbreak of myxomatosis usually does not occur in consecutive years (APB, n.d.; Williams *et al.*, 1995; DoA, 2003).

Rabbit calicivirus

The rabbit calicivirus was imported into Australia in 1991 to test whether it could be used as a biological agent to control rabbits. In 1995 the virus escaped from the testing facilities and quickly reached the mainland where it spread into South Australia, New South Wales and Victoria. Official release of the virus at various places began in 1996 and it quickly spread (Hinds *et al.*, 1996; Cooke & Fenner, 2002).

The initial effect of the virus on rabbit numbers was dramatic, with a mortality rate of more than 90% (Hinds *et al.*, 1996). However, since then it has been observed that the virus has a dramatic impact on rabbit populations in some regions (up to 90% mortality rate) while in others the virus did not seem to have any effect. It also appears that the virus affects different rabbit populations in a different way. In some areas rabbit numbers declined and stayed low, while in others the populations are slowly recovering (Hinds *et al.*, 1996; Cooke & Fenner, 2002). As with myxomatosis, rabbits can develop immunity against the virus. Young rabbits (up to five weeks) are naturally less susceptible while in rabbits between five and twelve weeks old susceptibility increases (Hinds *et al.*, 1996; Cooke & Fenner, 2002).

Despite the shortfalls in successfully controlling rabbit numbers both the myxoma virus and calicivirus are important factors for the control of rabbits. However, landholders should not rely on either of the viruses as the outbreaks are unpredictable and vary in effectiveness. Instead, other methods should be used to complement the reduction of rabbit numbers (Williams *et al.*, 1995; DoA, 2003).

Immunocontraception

Immunocontraception is a relatively new concept that is still in the development phase (Barlow, 2000). Immunocontraception involves the sterilisation of target animals through the manipulation of the target animal's immune system to attack its own reproductive system, usually the eggs or sperm. Ideally this would inflict life-long infertility as fertilisation of the egg can not take place. However, for the immune system to attack the reproductive system, it needs to be trained to recognise the reproductive system as

'foreign'. To teach the immune system to attack the eggs or sperms, proteins from the target animal's reproductive system (usually from the sperm coat and/or the egg's *zona pellucida*) need to be introduced into the body. This can be achieved by: a) bait (non-disseminating immunocontraception) or b) a self-spreading vector such as a virus (disseminating immunocontraception; Figure 1.2; Hinds *et al.*, 1996).

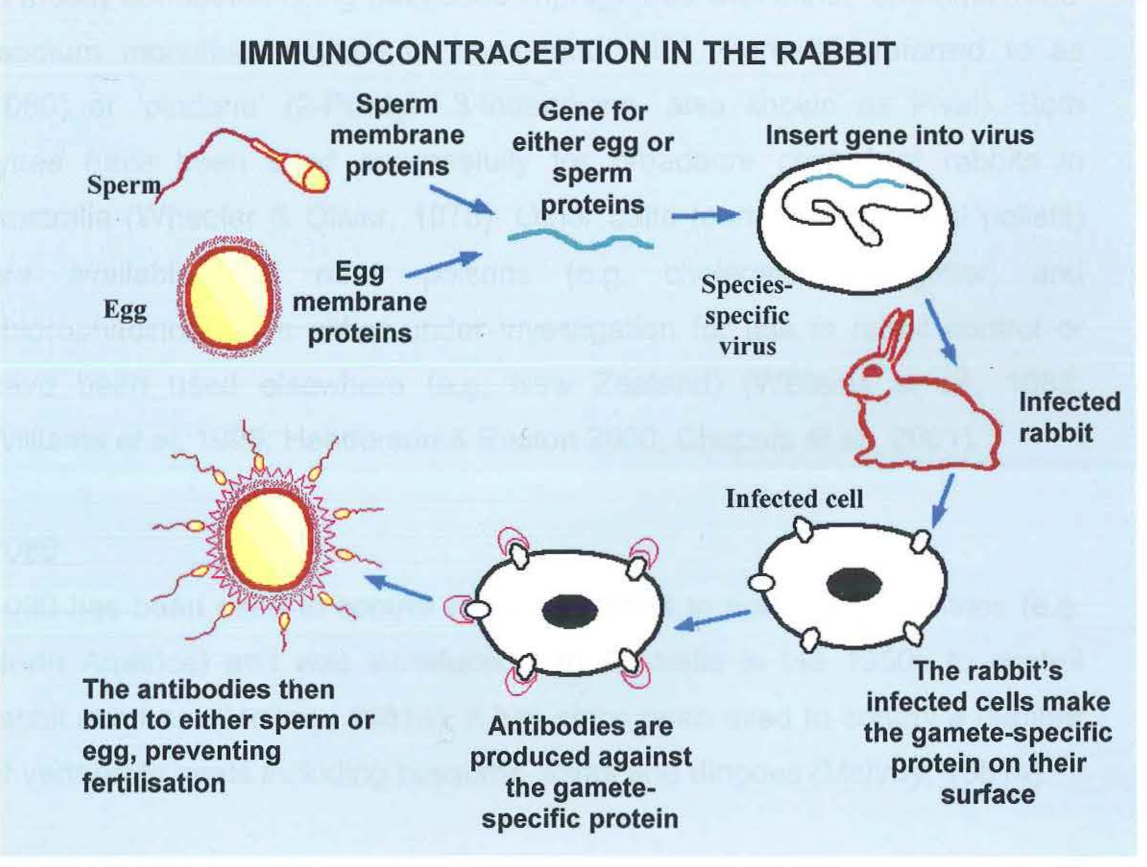

Figure 1.2 The concept of disseminating immunocontraception (modified from Tyndale-Biscoe, 1994).

For rabbit control it has been proposed to use the myxoma virus as a vector (Hinds *et al.*, 1996) as this virus is already in the population. It could also achieve a double effect by infecting and killing rabbits as before but, if the infected rabbit survives, it will be sterilised (Hinds *et al.*, 1996).

In theory, the concept of immunocontraception could be an effective way of reducing numbers of pest animals all over the world, and rabbits in Australia in particular (Barlow, 2000). However, several questions concerning efficacy, safety and other issues still need to be answered before initiating any control

program using immunocontraception (e.g. Hinds *et al.*, 1996; Twigg & Williams, 1999; Barlow, 2000; Twigg *et al.*, 2000).

Poison

Poisoning is considered the most cost-effective means of controlling large rabbit populations (APB, 1988a) and is therefore the most commonly implemented form of rabbit control in Australia (Williams *et al.*, 1995). Baiting is mostly conducted using oat seeds impregnated with either 'one-shot 1080' (sodium monofluoroacetate or compound 1080, hereafter referred to as 1080) or 'pindone' (2-Pivalyl-1,3-indandione, also known as Pival). Both types have been used successfully for broadacre control of rabbits in Australia (Wheeler & Oliver, 1978). Other baits (carrots and cereal pellets) are available and other poisons (e.g. cholecalciferol, gliftor, and chlorophacinone) are either under investigation for use in rabbit control or have been used elsewhere (e.g. New Zealand) (Williams *et al.*, 1986; Williams *et al.* 1995; Henderson & Easton 2000; Chapuis *et al.*, 2001).

1080

1080 has been used to control vertebrate pests in numerous countries (e.g. North America) and was introduced into Australia in the 1950s to control rabbit numbers (McIlroy, 1981a). It has since been used to control a number of vertebrate pests including possums, foxes and dingoes (McIlroy, 1981a).

1080 is a fast acting poison which is readily absorbed by the gastrointestinal tract and disturbs the nervous system and heart function. No antidote is available (Williams *et al.* 1995). 1080 can be administered in two ways: a) conventional and b) one-shot poisoning. During conventional baiting, rabbits become accustomed to eat the bait by free-feeding them before laying the actual poisonous bait (all oat seeds contain poison). For the one-shot method bait is prepared so that one in every 100 oats contains enough 1080 to kill three rabbits. This method relies on rabbits becoming used to eating the bait while they are being poisoned (Oliver et al, 1982; Williams *et al.*, 1995). As humans and domestic animals are very susceptible to 1080 and due to public concerns and health risks, 1080 cannot be used within most urban areas (Robinson *et al.*, 1990; Williams *et al.*, 1995; Twigg *et al.*, 2001).

Pindone

Pindone, an anticoagulant, has been used as a rodenticide and also has insecticidal properties (Kilgore *et al.*, 1942; Beauregard *et al.*, 1955; Saunders *et al.*, 1955). Pindone is available in two forms: a) pindone acid and b) pindone sodium salt. The pindone acid is an odourless and tasteless yellow powder which is largely insoluble in water while the sodium salt is water soluble (Williams, 1995; National Registration Authority (NRA), 2002). The form of pindone used depends on the producer. In Western Australia the insoluble form is used, while the product prepared by the Animal Control Technologies (RABBAIT®) contains the water soluble form.

Irrespective of the form of pindone used, it works by restraining an enzyme responsible for the formation of vitamin K. If vitamin K is not available within the body, the body cannot produce any blood clotting factors which in turn leads to severe haemorrhages. Vitamin K occurs naturally within the body and is also ingested, so this reservoir of vitamin K needs to be used before the pindone can have an effect on the body. It is therefore necessary that pindone is ingested over some period of time (Williams, 1995; NRA, 2002; Animal Control Technologies (ACT), 2003). The recommended way of poisoning with pindone is to free-feed rabbits and to then administer the poison using a three dose strategy. When using this strategy the poison is given three times with three to six days in-between the presence of poison (ACT, 2003). If a non-target animal is accidentally poisoned, the administration of vitamin K reverses the effect of pindone (Beauregard *et al.*, 1955; Robinson *et al.*, 1990; ACT, 2003). In Western Australia, pindone is therefore the only poison accepted for use in urban areas as it is less toxic than 1080 and vitamin K is readily available.

Disadvantages of the use of poisons

Neither 1080 nor pindone specifically kills only the intended species and the impact of poisons on non-target species is of great concern. However, target-specificity can be improved through understanding the ecology and feeding behaviours of target and non-target species and the subsequent development of a baiting program that uses differences in ecology and behaviour to target the appropriate animal. This can be achieved through

appropriate selection of bait, bait size and colour and the placement and presentation of bait (e.g. Brunner, 1983; Hartley *et al.*, 1999; Stafford & Best, 1999; Moro, 2001). One approach is the use of bait stations (Twigg *et al.*, 2001). Morgan (as cited in Twigg *et al.*, 2001) found that bait stations are most useful if the public has access to the baited area, if the area to be treated is small and if baiting is used in combination with other control methods. It is the research field of target and non-target feeding behaviour that this study contributes to.

Another disadvantage of 1080 and the pindone sodium salt is that they are both water-soluble compounds which quickly leach from bait when the bait is subject to dew, wet soil and rainfall (e.g. Griffith, 1959; Wheeler & Oliver, 1978, NRA, 2002). It is recommended that these are not used during wet weather (e.g. Williams *et al.*, 1995; NRA, 2002). Bait stations can also help with this problem as they provide protection from unfavourable weather (Twigg *et al.*, 2001).

1.4. Bold Park and Rabbits

Bold Park is a 437 ha 'A' class reserve within the Local Government boundaries of the Town of Cambridge and the City of Nedlands. The reserve is of high conservation value as it is one of the last remaining large bushland remnants on the Swan Coastal Plain (BGPA, 2000). It features a variety of plant communities including coastal heath and *Banksia* woodlands, which give refuge to a high diversity of animals. Unfortunately the bushland, as typical for bushland remnants, is threatened by the invasion of exotic animal species such as rabbits (BGPA, 2000).

The rabbit problem in Bold Park was recognised in the Bold Park Environmental Management Plan 2000-2005 (BGPA, 2000) and has since increased in magnitude (Buist, pers. com.). Currently, a large-scale revegetation program is under way to restore the vegetation condition of Bold Park. It has been noted that rabbits have been extensively grazing the newly planted greenstock, which may prevent the success of the revegetation program. To minimise the impact of rabbits on greenstock the implementation of a rabbit control program is warranted (Buist, 2004). Buist (2004) suggested

that poisoning with pindone would be the most appropriate way of reducing rabbit numbers. However, manufacturers currently advise to conduct baiting by laying bait trials through the feeding areas of rabbits, which makes access to bait by non-target species easy. As Bold Park is a refuge for native animals such as birds and reptiles, there is a need to minimise the risk to non-target animals as far as possible. Therefore, the use of bait stations is recommended. Twigg *et al.* (2001) assessed the efficacy of four different bait stations: a half-drum, a concrete slab supported on bricks, a sheet of corrugated iron supported on bricks, and a car tyre supported on bricks. The research showed that rabbits preferred the slab design but that the drum design was accepted when only the drum and tyre designs were used. The drum design also accounted for the least number of non-target species visits, so the use of the half-drum design was recommended (Twigg *et al.*, 2001). To test whether these findings apply to the use within Bold Park and do not differ between locations the drum and the slab design will be tested in Bold Park. The response of target and non-target species towards bait stations will be investigated in the two predominant plant communities in Bold Park, namely heath and *Banksia* woodland.

1.5. Aims of the thesis

The research aim is to investigate the uptake of non-poisonous RABBAIT® Poison-free Sterilised Oats 'free-feed' by target and non-target species. The oat seeds will be presented in two bait station designs: a) the drum and b) the slab design. The research will answer a number of questions:

1. Do rabbits take bait from the two bait station designs? If so, do they show a preference towards feeding from one of the two bait station designs?
2. Are the bait stations being visited by non-target species? If so, which species are visiting the bait stations?
3. If non-target species are visiting the bait stations, which bait station design has the least number of visits by non-target species?
4. Do the oat seeds used as bait germinate?

The next chapter gives details about the regional context of Bold Park. It also gives details about the environmental settings.

2. STUDY AREA: BOLD PARK

2.1. Location

Bold Park (383488 E, 646754 N) is a 437 ha 'A' class reserve, approximately eight kilometres from the City of Perth, Western Australia. It lies within the Local Government boundaries of the Town of Cambridge and the City of Nedlands and includes one large bushland area and three smaller areas to the north, west, and south. These smaller sections are separated from the main bushland by major roads. Except the north-eastern side of the main bushland, which is bordered by Perry Lakes reserve, Bold Park is surrounded by urban development (Figure 2.1; BGPA, 2000).

2.2. History of Bold Park

The Aboriginal Site Register identifies three ethnographic sites in and around Bold Park (BGPA, 2000). Site S2181, Stephenson Avenue Camp, lies within the Park boundaries. It has been recorded as a plant source and more recently as a meeting place between the two other sites, S2155, Lake Claremont, and S2182, Perry Lakes. Aboriginals have also lodged a claim over sections of the Perth metropolitan area. This claim is registered under the *Native Title Act 1993* and includes Bold Park (BGPA, 2000).

Henry Trigg was the first recorded European who, in 1843, developed part of the land now known as Bold Park, as a limestone quarry (BGPA, 2000). Just one year later, in 1844, Walter Padbury set up an abattoir, a tannery, and stock holding and other facilities. The land was sold to the Birch Brothers and in 1879 to Joseph Perry, before the City of Perth bought it in 1917. Aspects of this history still remain and include Perry House, Camel Lake, a pine plantation, and fire breaks (BGPA, 2000).

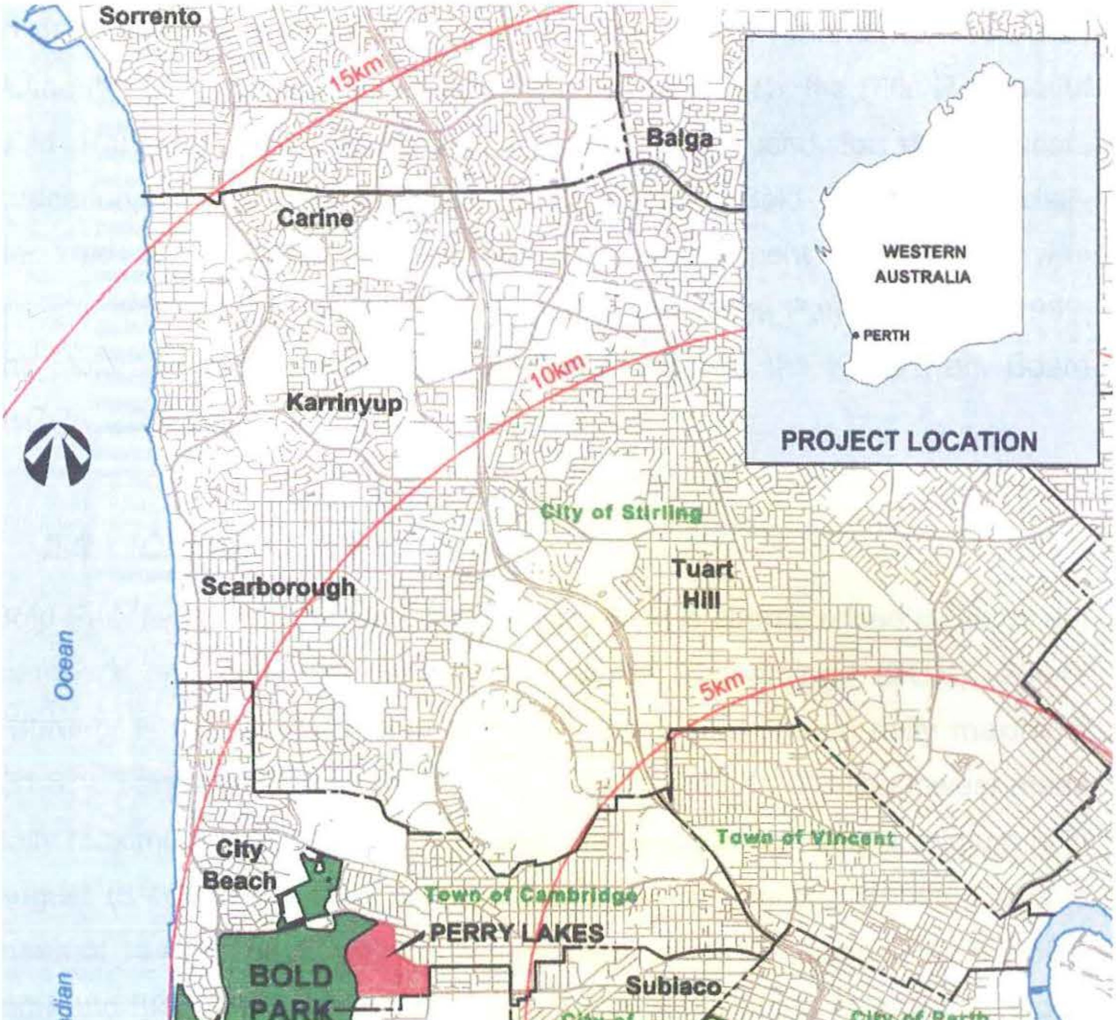

Figure 2.1 Location of Bold Park (Adapted from BGPA, 2000).

In 1983, the Environmental Protection Authority (Environmental Protection Authority, EPA) recommended that Swanbourne Beach, the Rifle Range and Bold Park be combined into a Regional Park used for conservation, education, and recreation (EPA, 1983). In 1998, Bold Park was officially declared an 'A' class reserve and the management of the park was transferred from the Town of Cambridge to the Kings Park Board. In 1999, the Botanic Gardens and Parks Authority replaced the Kings Park Board (BGPA, 2000).

2.3. Climate

Bold Park lies within the temperate zone, which is characterised by warm dry summers and cool wet winters (Bureau of Meteorology (BOM), 2004). February is the hottest month with both the highest mean daily maximum (31.8 °C) and the highest mean daily minimum (17.4 °C). The lowest mean daily maximum is in July (17.8 °C) and the lowest mean daily minimum is in August (8 °C). The mean annual rainfall of 788 mm is distributed over a mean of 114 rain days, with the highest monthly rainfall being in June (168.6 mm) and the lowest monthly rainfall in January (8.9 mm). Moisture loss due to evaporation is greatest during January, with 10.3 mm evaporation per day and lowest during June and July, with 2.2 mm evaporating per day. The mean daily sunshine is highest during December (11.8 h) and lowest during June and July (5.9 h; BOM, 2004).

2.4. Soils and Topography

Bold Park is situated on the Swan Coastal Plain, which extends from a subsidiary fault northwest from Bullsbrook in the north, to the Darling Scarp in the east, to the Collie-Naturaliste scarp in the south (McArthur & Bettanay, 1974). The Swan Coastal Plain consists of five major geomorphic elements derived from either fluviatile or aeolian activity: the Ridge Hill Shelf, the Pinjarra Plain, the Bassendean Dune System, the Spearwood Dune System, and the Quindalup Dune System. These are arranged parallel to the coastline with the Ridge Hill Shelf to the east being the oldest and the Quindalup Dune System, which is closest to the coast, being the youngest (McArthur & Bettanay, 1974).

The three coastal dune systems are of aeolian origin and were originally highly calcareous. However, with time, the carbonate was leached out, leaving siliceous sand in the Bassendean and Spearwood Dune Systems (Seddon, 1972; McArthur & Bettanay, 1974; McArthur, 1991).

Bold Park is located within the Spearwood and Quindalup Dune Systems (McArthur, 1991). The Quindalup sands, which are found on the western side of the park (BGPA, 2000), are typically pale grey sands above a deeper layer of cream to white sands (McArthur, 1991). The Spearwood sands, which are found on the eastern side of the park (BGPA, 2000), can be further divided into the Cottesloe and Karrakatta sands (McArthur & Bettanay, 1974). Cottesloe soils are found in the sections north of Oceanic Drive and in only two small areas within the main part of the park (BGPA, 2000). These soils consist of shallow yellow to brown sands over limestone. Karrakatta soils consist of deeper orange and yellow sand over limestone (Seddon, 1972).

The topography of Bold Park ranges from 10 m AHD (Australian Height Datum) to over 80 m AHD. Reabold Hill, with a hight of 84.8 m AHD, is not only the highest point within Bold Park, but also the highest point on the Swan Coastal Plain (BGPA, 2000).

2.5. Vegetation

Bold Park has a variety of vascular plants, including 298 native taxa, 43 non-local native taxa, and 164 weeds. Seven native taxa are priority flora species and 18 are of regional significance. The vascular plants belong to 287 genera of 95 families, with the most dominant being the Poaceae (42 taxa). In contrast, not much is known about the non-vascular plants in Bold Park (Keighery *et al.*, 1990; BGPA, 2000). Based on the occurrence of vascular plants, seven major vegetation communities have been identified by Keighery *et al.* (1990). These can be divided further into 30 plant communities (BGPA, 2000). The most dominant plant community is the 'Woodland of *Banksia attenuata* and *Banksia menziesii*, with emergent *Eucalyptus gomphocephala*, over a variable understorey on grey sand' (BGPA, 2000). A survey of the

overall condition of the bushland in 1998 revealed that, based on the percentage of weed and native foliage cover (excluding trees), 55 % of the bushland is in 'very poor' condition and 26 % is in 'poor' condition (Mattiske Consulting, 1998).

Despite the poor overall condition of the bushland, Bold Park is an important floristic link between other urban bushland remnants such as Kings Park, Herdsman Lake, Star Swamp Reserve, and Trigg Beach Reserve (BGPA, 2000).

2.6. Native fauna

The function of Bold Park as a floristic link with other bushland remnants is also important for fauna (BGPA, 2000). It is particularly important for migratory species such as birds. A total of 87 bird species have been recorded in Bold Park. However, a substantial number of these do not reside in Bold Park all year round. None of the bird species found at Bold Park are declared rare, threatened or vulnerable under State or Commonwealth legislation. However, the Carnaby's cockatoo (*Calyptorhynchus latirostris*) and the Peregrine falcon (*Falco peregrinus*) are listed under *The Wildlife Conservation (Specially Protected Fauna) Notice 1998*, the Red-tailed black cockatoo (*Calyptorhynchus banksii naso*) and the Square-tailed kite (*Lophoictinia isura*) are listed under the Department of Conservation and Land Management (CALM) Priority Fauna List and the Rainbow bee-eater (*Merops ornatus*) and the Fork-tailed swift (*Apus pacificus*) are listed under the Japan-Australia Migratory Bird Agreement Treaty and the China Australia Migratory Bird Agreement (How *et al.*, 1996; BGPA, 2000).

In the past, 33 mammal species occurred throughout the Swan Coastal Plain, including marsupials, monotremes, and eutherian mammals (Kitchener *et al.*, 1978). Today 18 of these 33 species still occur on the Swan Coastal Plain, but only six (five marsupials and one monotreme) have been sighted recently in urban bushlands (How *et al.*, 1996). The Common brushtail possum (*Trichosurus vulpecula*) was the only native mammal recorded during the 1996 study (How, *et al.*, 1996); bats were not sampled during this study.

Since then, two species of bats (Gould's Wattle Bat (*Chalinolobus gouldii*) and White-striped Freetail Bat (*Nyctinomus australis*)) have been recorded within the park (Ninox Wildlife Consulting, 1999).

So far, 35 herpetofauna species have been recorded within Bold Park, three frog and 32 reptile species (How *et al.*, 1996). However, How (1998) states that it is possible that not all species were sampled. None of the herpetofauna species found at Bold Park are declared rare, threatened or vulnerable under State or Commonwealth legislation, however, the carpet python (*Morelia spigroupa imbricata*) is listed under *The Wildlife Conservation (Specially Protected Fauna) Notice 1998* (How & Dell, 1990).

The invertebrate fauna of Bold Park is highly diverse with numerous species belonging to nine classes. However, the known number of invertebrates is only part of the complete assemblage, as the methods used by How *et al.* (1996) only sampled ground invertebrates.

2.7. Pest animals

Thirteen non-native species (five mammals, six birds and two invertebrates) are specifically mentioned in the Bold Park Environmental Management Plan (2000) for their impact or potential impact on native flora and fauna (BGPA, 2000). Rabbits have been identified as a serious threat to the bushland as the disturbance caused by them might 'increase weed invasion and impact on revegetation efforts' (BGPA, 2000). A report by Mac Shane (2000) on rabbit activity in a specific part of Bold Park revealed that rabbit numbers were high and could be counterproductive to any revegetation attempt. The report also suggested that many rabbits do not use warrens for shelter, but remain above ground and use thick understorey as protection (Mac Shane, 2000).

In 2000, the Friends of Bold Park enclosed part of the park with a rabbit proof fence. However, the project was not effective as the rabbits from inside the fence could not be eliminated. This was due to two factors: a) warren fumigation was not successful as most rabbits were living above ground and

b) because poisoning was not carried out due to concerns about the effect of pindone on non-target animals (Bold Park internal communication). The fence was partly removed in mid 2003.

Later trials by Buist (2004) in five different parts of Bold Park revealed high rabbit numbers during winter 2003 and a reduced number during summer 2003/2004. This was thought to be due to low reproduction during summer and the occurrence of calicivirus (see section 1.3) in the park. The impact of rabbits on greenstock was also under investigation. However, the information gained was insufficient to reach definite conclusions (Buist, 2004).

Bold Park is an important urban reserve. Rabbits pose a great risk to the regeneration of vegetation in Bold Park and it is therefore necessary to implement appropriate control methods to keep rabbit numbers at a low level. Due to conservation and public safety issues, the only appropriate methods are warren fumigation and poisoning with pindone. However, when poison is used non-target animals are at risk and it is warranted to limit the access of non-target species to the bait. One method of restricting the bait is to use bait stations and one of the research aims of this project is to identify non-target species visiting the bait.

The next chapter outlines two minor studies that were undertaken separately from the major field experiment. The first study examines whether the oat seeds used as bait have the potential to germinate. The second study aims at identifying the best sand for footprint analyses.

3. SUPPORTING TRIALS

This chapter will outline two experiments: a) an oat seed viability study and b) the assessment of sand types for optimal footprint identification. The first study was undertaken to determine whether any of the oats seeds used as bait would be able to establish into plants. This was conducted to ensure that the oat seeds used as bait would not add to the weed problem in Bold Park. The second study was undertaken to assess different types of sand for their ability to show clear animal footprints. The need for this study arose, as field conditions were not as good as expected.

3.1. Oat seed viability study

3.1.1. Introduction

The use of cultivated oat seeds (*Avena sativa*) for bait in any habitat has the potential of introducing a new environmental weed (Hussey *et al.*, 1997). This is of particular concern in declared conservation areas such as Bold Park where weed invasion is one of the major threats to native vegetation (Hobbs & Humphries, 1995). For this reason, RABBAIT® Pindone Oat Bait (hereafter referred to as pindone oat seeds) and RABBAIT® Poison-free Sterilised Oats (hereafter referred to as free-feed oat seeds) are gamma-sterilised and should not be able to grow into viable plants (ACT, 2003). To confirm the non-viability of oat seeds prior to their use in the field, germination and potting trials were conducted. In these trials, free-feed and pindone oat seeds were tested, with viable oat seeds used as controls.

3.1.2. Methods

Germination trial

Oat seeds were placed in petri dishes containing sterilised (15 psi/20 min) 7 % water agar. Ten petri dishes containing ten oat seeds each were prepared for each treatment. All petri dishes were sealed with parafilm to reduce moisture loss and to minimise the risk of contamination of the dishes with fungi and bacteria. The dishes were then placed randomly into a germination cabinet at 25 °C and a 12:12 light : dark cycle. As water agar was used, no water had to be administered during the trial.

The oat seeds were observed for signs of germination over a period of three weeks and their appearance was scored once a week. They were then left under room conditions in the laboratory for a further seven weeks and were then scored again to determine whether any changes had occurred, particularly to the RABBAIT® oat seeds. Oat seeds were considered to have germinated when the radicle and/or coleoptile had emerged.

Potting trial

Oat seeds were placed into free-draining seed-raising punnets (14 x 8 cm) containing a 1:1:1 mixture of peat : composted sawdust : river sand (standard potting mix used by the Botanic Gardens and Parks Authority, Plate 3.1). The oat seeds were then covered by approximately 1 mm of the potting mix. Ten punnets containing ten oat seeds each were prepared for each treatment. The punnets were watered to saturation and were randomly placed into four seedling trays. The trays were then grouped around a sprinkler in a fibreglass tunnel house, which was covered by 70 % shade cloth. The irrigation system was automated so that the punnets were watered to saturation for ten minutes per day. The doors to the tunnel house were left open and no artificial lighting was present.

Plate 3.1 Free-feed oat seeds on potting mix (peat, composted sawdust, river sand) before covering with ~1 mm of potting mix (Photo: Malin Kordes, 2004).

Oat seeds were observed for signs of germination and growth for ten weeks and were scored once a week. Oats were considered to have germinated when the coleoptile emerged through the potting mix. When emergence occurred, the size of the emerging seedling was recorded.

3.1.3. Results

Germination trial

Viable oat seeds germinated quickly, with 89 ± 3.5 % S.E. germinating within the first week. A germination rate of 99 ± 1.0 % S.E. was reached by week three (Figure 3.1).

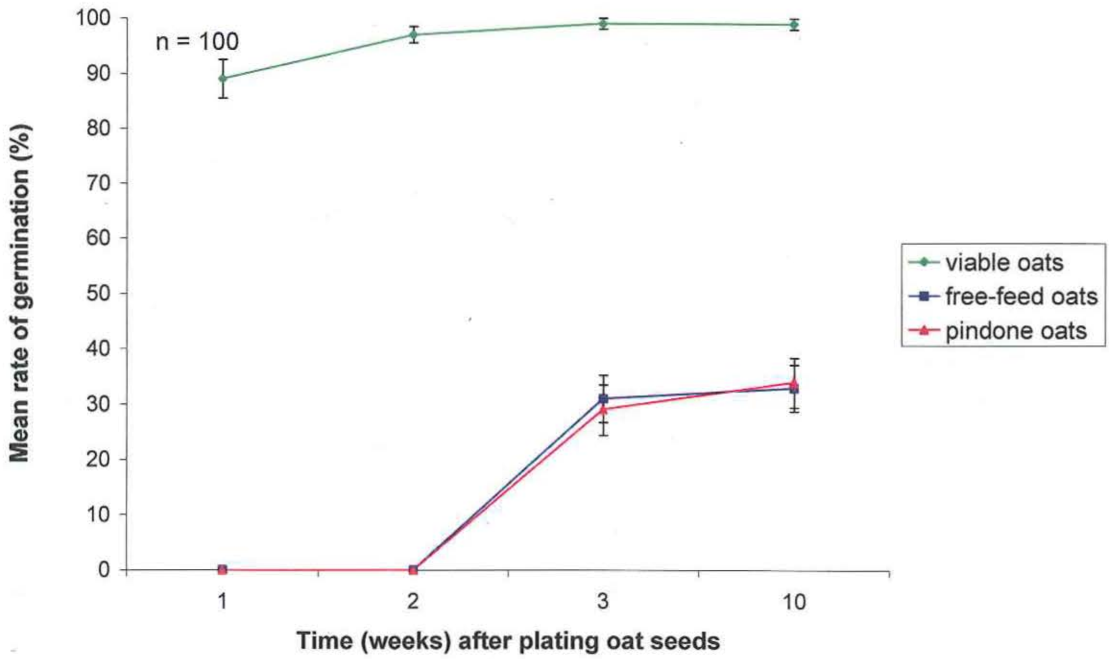

Figure 3.1 Mean rate (% ± 1 S.E.) of oat seed germination over a ten week period. Oat seeds were kept in a germination cabinet (25°) for three weeks and under laboratory conditions for a further seven weeks. Values are means of 100 seeds. Raw data can be found in Appendix A and the accompanying CD-ROM.

Pindone and free-feed oat seeds did not show any signs of germination until week three, when 29 ± 4.6 % S.E. pindone and 31 ± 4.3 % S.E. of free-feed oat seeds germinated (Figure 3.1). This rate did not increase considerably over the next seven weeks, with germination rates for pindone and free-feed oat seeds reaching 34 ± 4.5 % S.E. and 33 ± 4.2 % S.E., respectively. The graphical analysis of the results clearly shows that there is a difference between the growth of viable and sterilised oat seeds and no difference between free-feed and pindone oat seeds. I agree with Cherry (1998) that it is not necessary to perform statistical tests on results that show a clear difference. Therefore no formal statistical tests are needed. Although a third of pindone and free-feed oat seeds appeared to have germinated according to the set criteria, all failed to produce 'normal' coleoptiles.

Potting trial

The potting trial confirmed the results from the germination trial, namely that the pindone and free-feed oat seeds did not show signs of normal germination, and all seeds failed to develop any further. The viable oat seeds showed a mean germination rate of 96 ± 1.6 % S.E. after two weeks and reached their maximum germination rate of 99 ± 1.0 % S.E. by week three (Figure 3.2).

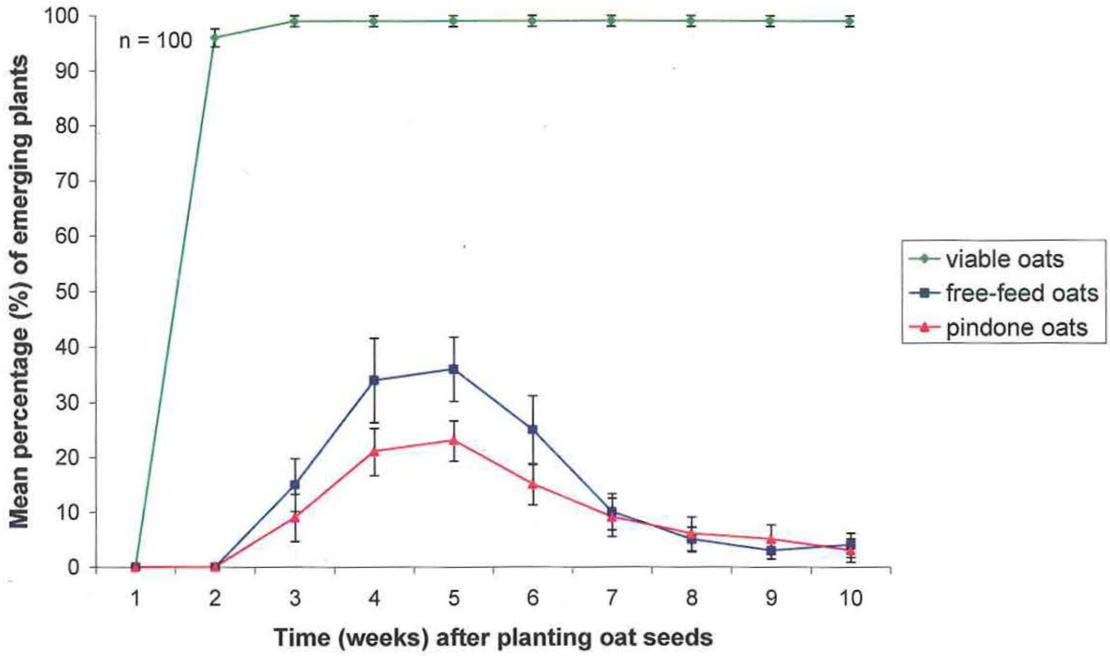

Figure 3.2 Mean rate (% ± 1 S.E.) of oat seed germination over a ten week period. Oat seeds were planted in potting mix and kept in a tunnel house. Values are means of 100 seeds. Raw data can be found in Appendix B and the accompanying CD-ROM.

The pindone and free-feed oat seeds showed signs of germination at week three (9 ± 4.3 % S.E. and 15 ± 4.8 % S.E., respectively) and reached their maximum rate at week five (23 ± 3.7 % S.E. and 36 ± 5.8 % S.E., respectively, Figure 3.2). However, as in the germination trial, the coleoptiles of both the pindone and free-feed oat seeds did not produce 'normal' coleoptiles. After week five, the rate of germinated oat seeds dropped because the abnormal coleoptiles disintegrated. By week ten only 3 ± 2.1 % S.E. and 4 ± 2.2 % S.E., respectively, of oat seeds were still exhibiting a coleoptile (Figure 3.2).

The average height (mm) of the emerging plant/germinants showed a significant difference between viable oat seeds and pindone and free-feed oat seeds (Figure 3.3). After germinating, the viable oat seeds quickly established into small plants, reaching an average height of 107.1 ± 2.37 mm S.E. by week three. The pindone and free-feed oat seeds did not develop further than the emergence of the coleoptile. The maximum average heights reached by the pindone and free-feed oat seeds were 2.7 ± 0.05 mm S.E. and 2.4 ± 0.12 mm S.E., respectively. As in the germination trial, the coleoptile appeared, however, none of the coleoptiles grew. On the contrary, the majority disappeared a few weeks after germination. The viable oat seeds, on the other hand, exhibited a relatively steady growth until week seven. After this time the plants showed signs of wilting and the growth plateaued (Figure 3.3,
Plate 3.2).

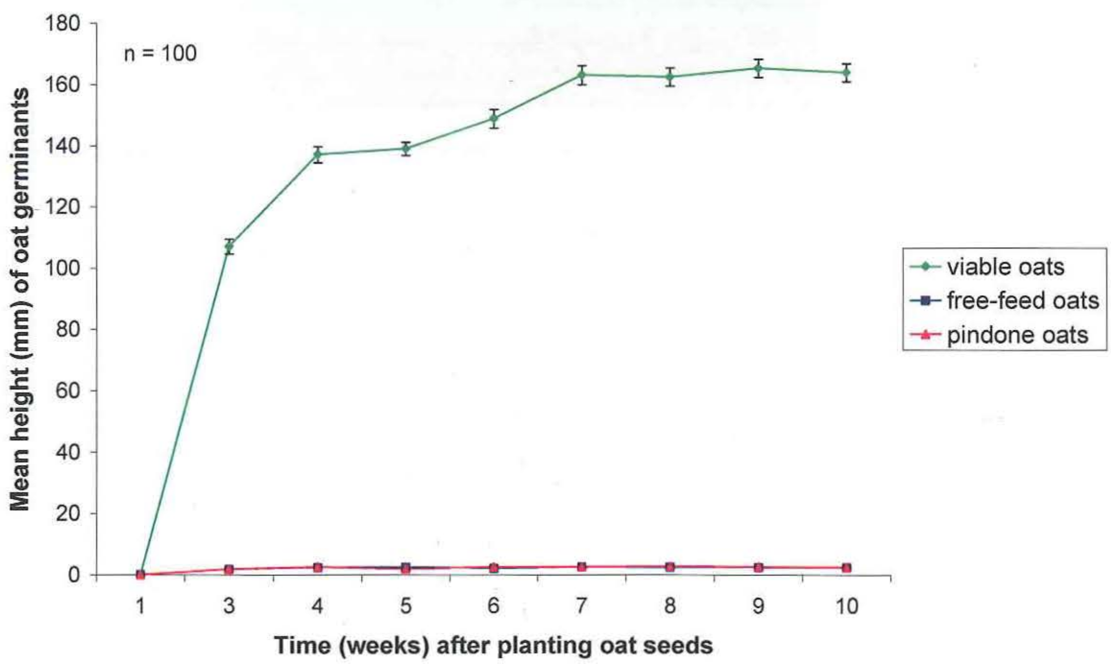

Figure 3.3 Mean height (mm ± 1 S.E.) of oat plants/germinants over ten weeks. Oat seeds were planted in potting mix and kept in a tunnel house. Values are means of 100 oat seeds. Raw data can be found in Appendix B and the accompanying CD-ROM.

Plate 3.2 Viable, pindone and free-feed oat seeds after eight weeks in the tunnel house. The viable oat seeds (second row from the front) show signs of wilting, while neither the pindone (front left) nor the free-feed oat seeds (front right) developed into plants (Photo: Malin Kordes).

3.1.4. Discussion

The germination and potting trials confirmed that the RABBAIT® oat seeds would not be able to establish themselves into fully grown plants. Although germination was observed in up to 36 % of free-feed and 34 % of pindone oat seeds none of them developed any further than the emergence of the coleoptile. In fact, when planted in soil, the coleoptile often disappeared. This was due to the disintegration of the abnormal coleoptiles. These results confirm the claim of Animal Control Technologies (2003) that the oats are not able to develop into oat plants.

In both trials, viable oat seeds germinated quickly and established into juvenile plants. During the potting trials the viable oat seeds showed continuous growth until week seven, when the plants showed signs of wilting. This is possibly due to drying of the potting mix, as the sprinkler system in the tunnel house was turned off in week five. This was not detected until week six. From week seven onwards the outermost leaf of almost all oat plants was wilting and by week 9 the second leaf was wilting. However, the plants were still growing, with the fourth and fifth leaf appearing around week nine and ten, respectively. But, as the size of the plant was measured from the base to the tip of the tallest leaf, and the longest leaves were the ones that wilted, the actual size measurements did not reflect the actual growth (see Appendix B).

Following on from the results of these trials, it is recommended that, if oat bait is used for control programs, only bait that is prepared with sterilised oat seeds should be used. If viable oat seeds are used, the seeds that are not consumed could germinate, which could result in the establishment of oat plants. Although not investigated during these trials, the established plants could have the potential to spread and invade other areas as a weed (Hussey *et al.*, 1997).

3.2. Assessment of sand types for optimal footprint identification

3.2.1. Introduction

To reveal good footprints sand should neither be too coarse, nor too soft (Glen & Dickman, 2003). Orell (2003) suggests that yellow 'brick-layers sand' is the best sand type to reveal clear and easily visible footprints, especially for small mammal surveys. The sand at the bait stations in Bold Park (see section 4.2.3) was not always ideal for observing clear footprints of visiting animals, as the sand covering the hard surface was not deep enough or contained too much organic matter. In order to investigate which sand type would reveal good footprints of birds in addition to mammal footprints, different sand types were evaluated for their ability to produce good footprints. In addition to the recommended yellow sand two other sand types were tested: white silica sand and 'transitional' sand, which includes layers of coffee rock.

3.2.2. Methods

To test the different sand types for their ability to hold prints, sand was laid out on quadrats. All sand types were tested under two different conditions: completely dry (simulating good weather conditions) and saturated (simulating rain). Those two conditions were chosen because they were the two conditions under which footprints were particularly indistinct. To find the best sand type it was assumed that the sand with the best results in dry and wet conditions would also reveal the best prints when the moisture content ranged anywhere between these extreme conditions.

The experimental sand plots used were made of a wooden frame (57 x 57 cm) to which chicken wire was attached. The mesh was then layered with sheets of newspaper to prevent the sand from falling through. The dry sand was spread on top and smoothed out with a piece of cardboard. The plots for the 'wet' treatment were then watered to saturation. Some free-feed oat seeds were placed in the middle of each sand plot to attract birds (Plate 3.3).

Plate 3.3 Sand plot of dry white silica sand with free-feed oats to attract animals used for the assessment of footprints (Photo: Malin Kordes, 2004).

The sand plots were placed outside. Animals that visited the plots could be identified and matched to their tracks. Once an animal was identified and had left its footprint on as many of the sand plots as possible, the prints were photographed and examined for clarity as well as longevity. The latter was important as the sampling times in the field were approximately 24 hours apart and the prints needed to stay reasonably well preserved in order to be clearly visible at the sampling time.

Clarity of prints was assessed by the sharpness of the imprint, that is, whether the sand was falling back into the print or remained stable, forming relatively sharp edges. The longevity was assessed by leaving the sand plots with prints overnight and assessing the clarity of the prints again the next morning. Assessment was made on a scale from 1 to 5, with one being poor clarity or longevity and 5 being good clarity or longevity.

3.2.3. Results

Bird footprints on dry sand did not result in clear prints, independent of the type of sand (Plate 3.4, Table 3.1). The prints on dry sand were also short-lived. This was particularly the case when the sand plots were subject to wind.

Plate 3.4 An example of a dove footprint in dry, white silica sand (Photo: Malin Kordes, 2004).

Table 3.1 Results of sand plot assessment for clarity and longevity of bird footprints on a scale from 1 to 5. 1 is poor and 5 is good clarity/longevity.

Sand type	Clarity	Longevity
Transitional sand, dry	1	1
Transitional sand, wet	4	4
White silica sand, dry	1	1
White silica sand, wet	4	3
Yellow 'brick-layers' sand, dry	2	2
Yellow 'brick-layers' sand, wet	4	4

When sand was watered to saturation, full bird footprints were rarely visible on the sand and these usually belonged to magpies and ravens. The only visible marks from doves were claw imprints. However, in the few instances that full prints were observed, these were fairly clear and remained so over night (Table 3.1).

3.2.4. Discussion

The sand plot trials revealed that none of the tested sand types resulted in good footprints when completely dry or wet. When compared with the condition of footprints in dry and wet sand in the field it did not seem likely that the introduction of any of the tested sands would have made a significant difference to the visibility of footprints, even if optimal conditions were present. Optimal conditions, according to Trigg (1996), are when the sand is firm and moist. During the field trial, these conditions were present a few times without any manipulation and this confirmed that tracks were best during these conditions. However, it would not have been possible to constantly keep the sand plots at a suitable moisture level.

Other considerations also influenced the decision on whether sand should be brought into the park. Firstly, the sand, particularly shallow sand over a hard surface, was subject to erosion during heavy rainfall. This meant, that if sand would have been brought in to form sand plots, it most likely would have had to be replaced on a regular basis. Secondly, it needed to be considered that any material brought into the park was a possible carrier of plant pathogens, particularly of dieback fungus (*Phytophora cinnamomi*).

Plant pathogens have been identified as a management issue in Bold Park (BGPA, 2000) and particular care is undertaken with any material that is brought into the park. To reduce the risk of introducing contaminated sand into the park, the sand needed either to be obtained from a site that is certified to be free of plant pathogens or to be sterilised. This would have been expensive and time consuming. Furthermore, by the time the sand plot assessment was analysed, all prints occurring at the stations had been identified and matched to the appropriate animal. It was therefore not as necessary to obtain clear footprints from the sand plots.

Considering these factors it was decided that the amount of resources and time needed to bring in sand from another location was not in any correlation to the possible gain. Therefore, for bait stations where the sand conditions were not suitable for good footprints, sand was collected adjacent to the station and placed around it.

In conclusion it can be said that yellow 'brick layers' sand would be more suitable for the assessment of footprints than white silica sand, particularly if the sand is moist. However, the relationship between obtaining better footprints and the effort of bringing sand to a particular location needs to be assessed on an individual basis. In some cases it might be necessary to bring in sand, while in others dentification of unclear or uncertain footprints may be achieved through other, less time and labour intensive means like photographs and taking of videos.

The next chapter outlines the main research, which was undertaken in order to evaluate the use of bait stations during a baiting program. The study assessed whether rabbits prefer to take bait from a particular bait station design, which kind of non-target species are visiting the stations and whether these show a preference towards one of two bait station designs.

4. AN INVESTIGATION INTO BAIT UPTAKE BY TARGET AND NON-TARGET ANIMALS

This chapter outlines the assessment of bait stations, investigating whether rabbits prefer to take bait from a particular bait station design, which kind of non-target species are visiting the stations and whether these show a preference towards one of two bait station designs. These questions were addressed in order to provide recommendations to the management of Bold Park about the use of pindone to control rabbits in the park.

4.1. Introduction

The use of poison is believed to be the most cost-effective method for the control of rabbits (APB, 1988a). Baiting in Western Australia is conducted using oat seeds, pellets or carrots impregnated with either 'one-shot 1080' (sodium monofluoroacetate) or 'pindone' (2-pivalyl-1,3-indandione). Both poisons have been used successfully for broadacre control of rabbits in Australia (Wheeler & Oliver, 1978). However, controlling rabbits in urban areas is not as easily accomplished. The use of 1080 is problematic due to public health concerns and the risk to domestic animals (Twigg *et al.*, 2001).

Pindone is preferable because of its low secondary poisoning risk to cats and dogs and the availability of a reliable antidote, Vitamin K (APB, 1988a). In addition, an extended period without rainfall is required for baiting with 1080, whereas baiting with pindone is almost equally effective in all seasons. Pindone is therefore the only recognised poison available for the control of rabbits in urban areas (Robinson *et al.*, 1990). However, if the bait is laid in trails, non-target animals are at risk of being poisoned and it is therefore advised to reduce the risk to non-target animals. One way to reduce the risk is to administer bait in bait stations (Twigg *et al.*, 2001).

4.2. *Methods*

4.2.1. Bait specifications

This study used RABBAIT® Poison – free Sterilised Oats (thereafter referred to as free-feed oat seeds), a product from the Animal Control Technologies Pty Ltd. The product does not contain any poison but is otherwise identical to RABBAIT® Pindone Oat Bait. Both products are gamma-sterilised to reduce the risk of unwanted germination (see section 3.1). The husks of the oat seeds are also dyed green to decrease the uptake by birds (ACT, 2003), as they prefer red or yellow food (e.g. NRA, 2002; ACT, 2003).

4.2.2. Bait station design

Two different bait station designs were used during this study. The designs follow Twigg *et al.* (2001).

(a) *'Drum' design*

The drum design was made out of a 200 L plastic drum cut in half lengthwise. One access hole was cut into each end of the drum-halves. The drums were then placed cut side down. The original colour of the drums was a bright blue, which made them highly visible in the bushland. To reduce the risk of park visitors seeing and therefore accessing the drums, they were painted dark green using outdoor paint. To reduce interference with the drums if a member of the public accessed it, a sticker about the project with a contact number was placed on each drum (Plate 4.1).

(b) *'Slab' design*

The slab design was a 60 x 60 cm concrete slab supported on bricks (two bricks high). The bricks were arranged in a square so that the corners of the slab were supported, while animals had access to the bait from all four sides (Plate 4.2).

Plate 4.1 A 200L plastic drum cut in half lengthwise was used for the 'drum' bait station design (Photo: Malin Kordes, 2004).

Plate 4.2 A 60 x 60 cm concrete slab supported on bricks was used for the 'slab' bait station design (Photo: Malin Kordes, 2004).

4.2.3. Placement of bait stations

The research was carried out in three areas within the northern part of Bold Park: Oceanic Precinct, Reabold Hill, and Eastern Gateway (Figure 4.1). These three areas were selected because they are focus areas for the revegetation program carried out in the park (BGPA, 2000). The major community types within these areas are a) *Banksia* woodland with an emerging *Eucalyptus gomphocephala* canopy, and b) tall closed heath dominated by *Dryandra sessilis* (BGPA, 2000). In order to represent both community types in the project, an equal number of bait stations was placed within each community type (woodland and heath/shrubland).

The exact location and number of the bait stations were determined by the location and number of active warrens. Prior to the commencement of the trials, the three focus areas (Reabold Hill, Oceanic Precinct, and Eastern Gateway) were surveyed for active rabbit warrens. A total of sixteen warrens in four research sites were located: four in heath at Oceanic Precinct; four in heath at Reabold Hill; four in *Banksia* woodland at Oceanic Precinct; and four in *Banksia* woodland at Eastern Gateway (Figure 4.1).

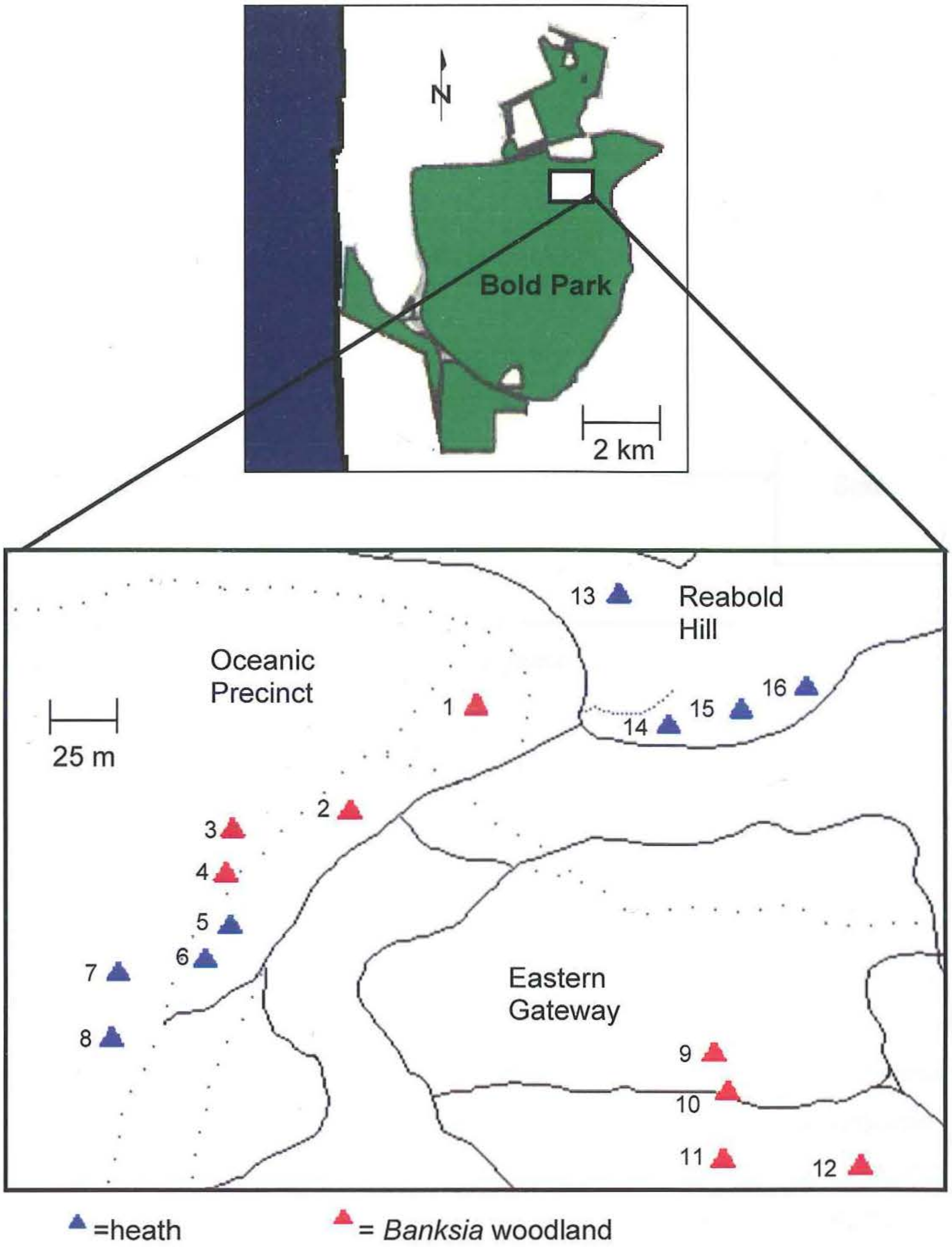

Figure 4.1 Location of bait stations within Bold Park. (Map adapted from BGPA, 2000).

One bait station of each type was placed near each warren. The bait stations were permanently set up approximately 15 m from the warren, one on each side. As the warrens were mainly very close to a walking track, most stations were positioned parallel to the path (Figure 4.2). The stations were placed on existing sand plots, which were cleared of any leaf litter. These plots were not of uniform size, as vegetation surrounding the stations could not be cleared.

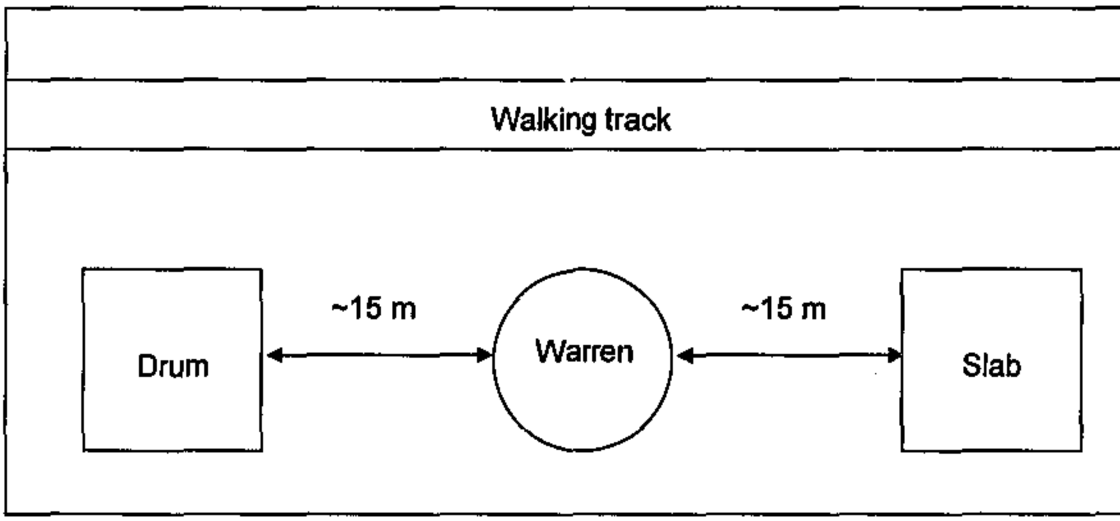

Figure 4.2 Positioning of bait stations in relation to paths.

4.2.4. Bait presentation

The bait was presented in green plastic saucers with a diameter of 30 cm and a height of 4.5 cm. To prevent larger animals, especially rabbits, from sitting in the bait and /or dislodging the saucer, half a brick was placed in the middle of the saucers before the bait was poured in (Plate 4.3). The stations were baited with 1 kg of free-feed oat seeds the afternoon before each sampling period. If the amount of bait left in the saucer reached 100 g or less during the sampling period, the bait was topped up. If a top-up was required, the amount added depended on the day of sampling: less was added during the last days of sampling. During the non-sampling periods a sufficient amount of bait was placed in the saucers to ensure that animals visiting the stations remained habituated to the presence of bait.

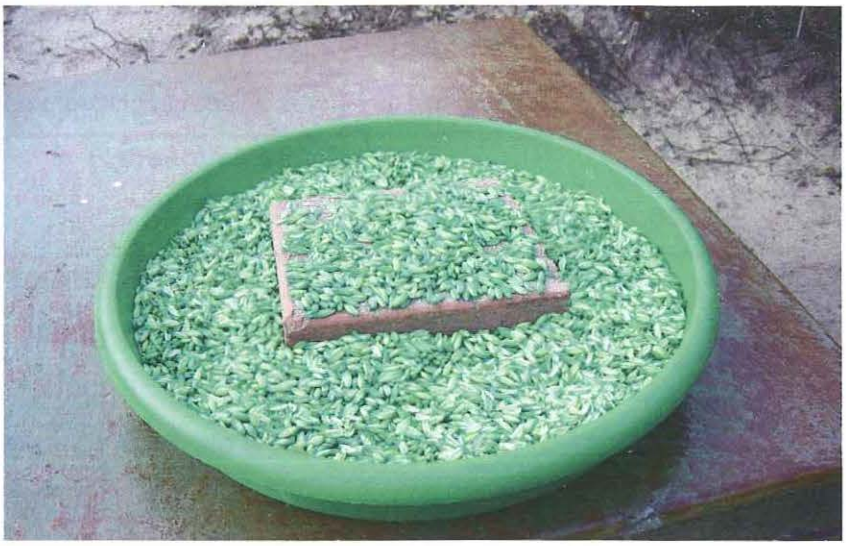

Plate 4.3 Bait presentation: A plastic saucer was used for the presentation of bait. A brick was placed in the saucer to prevent larger animals from sitting in the bait (Photo: Malin Kordes, 2004).

4.2.5. Sampling design

Data was collected from April 2004 until September 2004 over five sampling periods. The sampling of all 16 warrens could not be accomplished at the same time, therefore the warrens were split into two groups containing eight warrens each (group 1 and group 2). Each group contained two randomly chosen warrens from each research site (Table 4.1). Each of the five sampling periods therefore consisted of: the sampling of warrens in group one for seven days, a seven day break (no sampling) and the sampling of warrens in group two for seven days.

During each sampling period each bait station was checked for bait uptake and target and non-target species visitation each morning for seven days. The checks began as soon as sufficient light was available to observe footprints left behind on the sand plots.

Table 4.1 The grouping of rabbit warrens into two groups.

Research site	Warren ID	
	Group1	Group2
Oceanic Precinct, predominantly *Banksia* woodland	1	2
Oceanic Precinct, predominantly *Banksia* woodland	3	4
Oceanic Precinct, predominantly heath	5	6
Oceanic Precinct, predominantly heath	7	8
Eastern Gateway, predominantly *Banksia* woodland	10	9
Eastern Gateway, predominantly *Banksia* woodland	11	12
Reabold Hill, predominantly heath	13	15
Reabold Hill, predominantly heath	14	16

Target and non-target visitation

To determine what kinds of animals visited the bait stations, all animal tracks visible on the sand plot in and around the stations were examined each morning and identified as best as possible (see below). During the first sampling period all the different tracks observed were photographed. Of each track type multiple photographs were taken to capture different sand conditions and quality of the tracks. Tracks were recorded as present or absent as the number of individual tracks could not be determined. Also photographed were diggings and scats. Scats were collected to allow for verification of their identification. The identification, number and location (inside or outside the station) of the tracks were recorded. Also recorded and identified were other traces such as scats and scratchings. If scats were

deposited inside the saucer, they were removed as much as possible. The plots were also checked for spillage of oat seeds and whether the spilled oat seeds were outside the station and therefore visible. For new or unidentifiable tracks and other traces, photographs and sketches were made for later identification. A general description including size, shape, and colour of the tracks and other traces were also recorded. The sand plots were then smoothed out with a hand-broom to erase the tracks in readiness for the next 24 hours of activity.

Identification of tracks

For the identification of animals that visited the stations several techniques were used. For mammal species, track identification was first attempted by consultation of Trigg (1996). To verify the identification of tracks or to differentiate between species, scats, diggings and feeding signs (see Appendices D, E, F) were considered as well. The identification of rodent scats was verified by Keith Morris and Brent Johnson from the Department of Conservation and Land Management (CALM). In the field rodents were often seen when the bait stations were checked (see Appendix C), so that they could be identified using Menkhorst & Knight (2001) and matched to the appropriate track.

The identification of birds visiting the bait stations proved to be more difficult, as no literature was found that dealt with the identification of birds by their tracks. Also, no other material (e.g. feathers) by which identification could have been accomplished was left behind. However, some useful information on track shape and ways of identification was provided by Claire Stevenson (Birds of Perth), Peter Catling (CSIRO) and Jennifer Jackson (CALM). Actual identification of birds was achieved by observations of birds when the bait stations were checked and through observation of birds throughout the assessment of sand types (see section 4.2, Appendix C). Additionally birds were observed deliberately wherever possible and if good prints were produced these were examined and, whenever possible, photographed.

Lizard tracks could not be identified to species, as only a small number of lizards visited the bait stations and these tracks were not good enough to allow for any differentiation between species.

Measurement of bait uptake

The amount of bait removed from a station was measured by weighing the oat seeds left in the saucer and subtracting this from the previous day's weight. The oat seeds were weighed by tipping them into a cotton bag which was then weighed with a 2 kg spring balance to the nearest 10 grams. The weight of the cotton bag was also recorded and subtracted from the measured weight. The oat seeds were then returned to the saucer. All spilled oats were removed daily by sweeping them up with a dustpan and hand-broom and sieving them through a 2 mm sieve to remove most of the sand. These oat seeds were regarded as taken and they were therefore disposed. Any remaining oat seeds were covered up as much as possible to allow accurate assessment of tracks on the sand plots the next morning.

4.2.6. Changes to bait presentation

During the first two sampling periods (April, May) it became clear that the method of bait presentation described above (see 4.2.5) was not ideal for a number of reasons:

1. It was originally planned to leave bait in the bait stations for the whole duration of the project, so after the first baiting period for group one, bait remained in the bait stations for 21 days. During this time rodents and birds became habituated to the permanent presence of oat seeds. Rodents had established entries to their burrows underneath most of the drums and birds were increasingly visiting the bait stations. This suggested that, if access to bait was unrestricted, rodents and birds would permanently feed from the stations.
2. A large amount of husks were scattered inside and outside the stations when they were set for the second sampling period. The majority of husks were left behind by rodents, who de-husk the oat seeds and only feed on the kernel (pers. obs.). Rodents also cached oat seeds. Piles of husks were found up to approximately 1.5 m from

the bait station. The amount of husks left behind made it hard to prepare the sand plot for the next sampling period.

3. During the sampling periods large amounts of oats were spilled by birds. This led to less accurate weight measurements and therefore overestimates of bait uptake, because the initial sampling design classified all spilled oats as eaten.

In order to improve the bait uptake estimates for the remaining three sampling periods, the following changes were made to the way bait was presented and data was collected:

1. To prevent rodents and birds becoming too accustomed to an ever-present food source and to reduce the spillage of husks into the surrounding bush, all bait was removed between sampling periods and was only present during the sampling week.
2. To reduce the amount of oat seeds spilled by birds during the sampling periods an attempt was made to make the bait inaccessible to them. To make the stations 'bird proof' through for example fencing was not possible, as this would have meant to exclude the target animal (the rabbit) from the stations as well. The difference in activity time was thought to be a useful difference in behaviour that could be exploited. Rabbits are mainly nocturnal, while birds are diurnal. It was therefore thought that if the bait was not available during most of the day birds would not get habituated to the presence of bait, which in turn would reduce the amount of visits and therefore spillage of oat seeds. To make the bait inaccessible during the day, the brick was removed from the saucer and a second, identical saucer, was placed on top of the one containing the oat seeds. To prevent animals from removing the cover, the brick was placed in the top saucer (Plate 4.4). Each saucer was covered up after it was sampled in the mornings and uncovered late the same afternoon. As sampling started as soon as sufficient light was available and lasted until early to mid-morning and safety reasons did not permit to remain in the park after sundown, birds still had a short period during which the bait was accessible to them. However, if oat seeds were spilled, the spillage was small

enough to be retrieved, sieved, and weighed. Thus a more accurate estimate of bait-take by visiting animals could be achieved.

Plate 4.4 Bait presentation during the day from the third sampling period onwards. To cover up the oat seeds, a second saucer was placed on top of the one containing the oat seeds. The brick functioned as a weight, so that animals could not remove the cover (Photo: Malin Kordes, 2004).

4.2.7. Statistical analysis

The study was observing: a) the bait uptake and b) the number of visits by animals over time at two different bait station designs. Even though the bait stations were placed in two community types, these communities were not distinctively different and in one case one merged with the other. Therefore the two community types were not considered to be valid independent factors in the analysis. Consequently, the analyses only tested whether there was a difference between the drum and the slab designs but not whether bait uptake or species visitation differed between the community types.

As the measurements from a single bait station could not be considered to be independent from earlier measurements, the appropriate way of analysing the data was a repeated measures analysis of variance (ANOVA) (Dytham, 2003). However, as the way of bait presentation was changed after the second sampling period the first two sampling periods had to be analysed separately from the last three sampling periods. For these, a repeated measures ANOVA was no longer appropriate because measurements were taken less than three times (Dytham, 2003). Therefore a one-way analysis of variance was deemed appropriate.

Analysis of total bait uptake

A one-way ANOVA could not be used for the analysis of the first two sampling periods, as the assumptions of homogeneity of variance and normally distributed data were not met, despite the use of various transformations. Instead, the non-parametric equivalent to a one-way ANOVA, the Mann-Whitney-U test, was used to test for differences in bait uptake and visitation to the stations. This test performs best when the data comes from a continuous distribution but functions rather well when there are ties. The outcome of this test depends on the shape of the distribution of data. As the shape of the distributions for the drum and slab designs were different, it could only be said whether one of the bait station designs had higher bait uptake (Norušis, 2000). The Mann-Whitney-U test is less powerful than an ANOVA but the chances of classifying results as statistically significantly different, when they are not is reduced (Dytham, 2003).

For the last three sampling periods a repeated measure ANOVA was used to determine whether the type of bait station had a significant effect on the amount of bait taken (within subject factor: sampling period; between-subject factor: bait station design). To meet the assumptions of an ANOVA, data were transformed using various transformations. However, the assumption of homogeneity of variance could not be met with any of the transformations. Following the advice of McGuinness (2002), the data was screened for outliers and it was found that in every group with large variances outliers were the problems. In all cases the outliers were exceptionally low values of bait uptake as rabbits did not visit. As the feeding of rabbits is the subject of interest, the outliers were excluded from the analysis. The data was then log-transformed (ln[x+1]). For any statistically different effects that involved more than two factors a pairwise comparison using the Bonferroni method was used to find where the differences occurred.

Analysis of total target and non-target species visitation

To analyse the visits by target and non-target animals the same approach was taken as above. However, none of the data sets, even when transformed, met the assumptions of homogeneity of variance and normally distributed data. Therefore a Mann-Whitney-U test was used on each of the data sets in the same way than it was used on the weight data for the first two sampling periods.

4.3. *Results*

4.3.1. Analysis of bait uptake

During the first sampling period, the bait removal from the two bait station designs was not significantly different (Mann-Whitney U test, $Z = -1.21$, $p>0.05$, Figure 4.3). In the second sampling period, however, significantly more bait was removed from the slab than the drum bait stations (Mann-Whitney U test, $Z = -4.19$, $p < 0.001$, Figure 4.3).

There was a significant effect for sampling period as well as for bait station design (Table 4.2). There were no significant bait station and sampling period interaction effects, therefore it was valid to test for differences between bait stations and sampling periods (Table 4.2). A Bonferroni pairwise comparison of the main effects showed that animals removed significantly more bait during sampling period 4 than in sampling period 5 (mean difference: 0.219, $p<0.02$) and that the amount of bait taken at the slabs was significantly greater than at the drums (mean difference: 0.517, $p<0.01$, Figure 4.3).

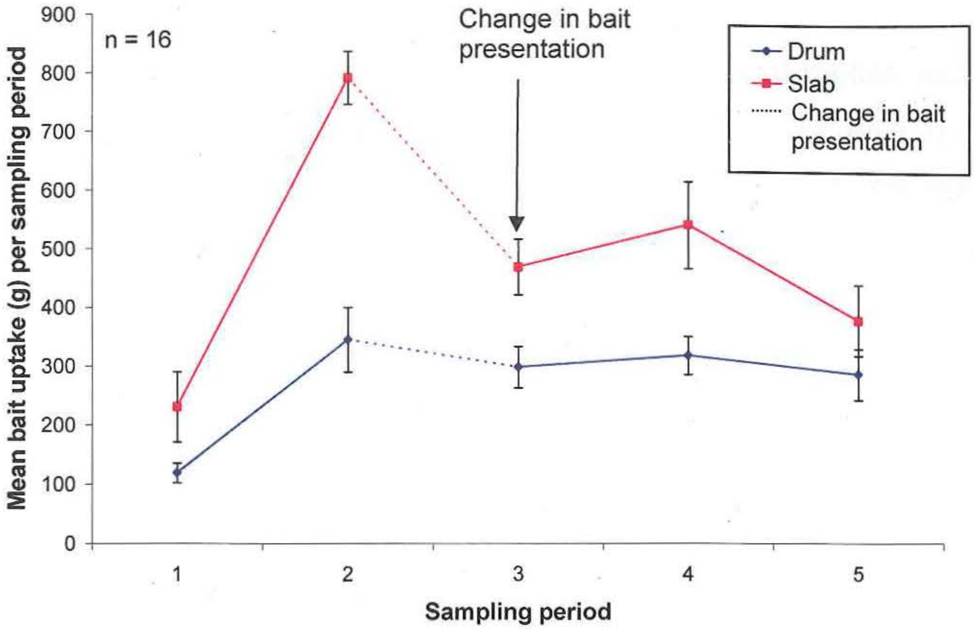

Figure 4.3 Mean bait uptake (g ± 1 S.E.) at two different bait station designs over five sampling periods. Sampling period one and two differ from sampling periods three to five in the way the bait was presented (illustrated by the dotted line between sampling period two and three). Values are means from 16 bait stations.

Table 4.2 Results of the repeated measures ANOVA testing differences in the total bait uptake between bait station designs over five sampling periods. Values are sphericity assumed values (Mauchly's W: 0.824, p>0.05). The data excluded outliers. * = significant at the p < 0.05 level.

Factor	df	Mean square	F-Value	P-Value
Sampling period	2	0.326	0.45	**0.039** *
Bait station design	1	5.412	12.481	**0.002** *
Sampling period x Bait station design	2	0.146	1.54	0.224

4.3.2. Analysis of rabbit visits

There was no significant difference between numbers of rabbits visiting the slab or the drum design during sampling period one (Table 4.3). During sampling period two the difference in visits to the bait stations was significant (Table 4.3). During both sampling periods more rabbits visited the slab designs than the drum designs (Table 4.3, Figure 4.4).

Following the change in bait presentation, none of the subsequent three sampling periods showed a significant difference between rabbit visits to the two bait stations (Table 4.3). As the increasing numbers of rabbit visits show (Figure 4.4), the change in bait station presentation did not affect the number of rabbit visits to the stations. However, Figure 4.4 shows clearly that there are always more rabbits visiting the slab design than the drum design. Also, the margin between visits to slabs and visits to drums decreased over time, with rabbits increasingly visiting the drums (Figure 4.4).

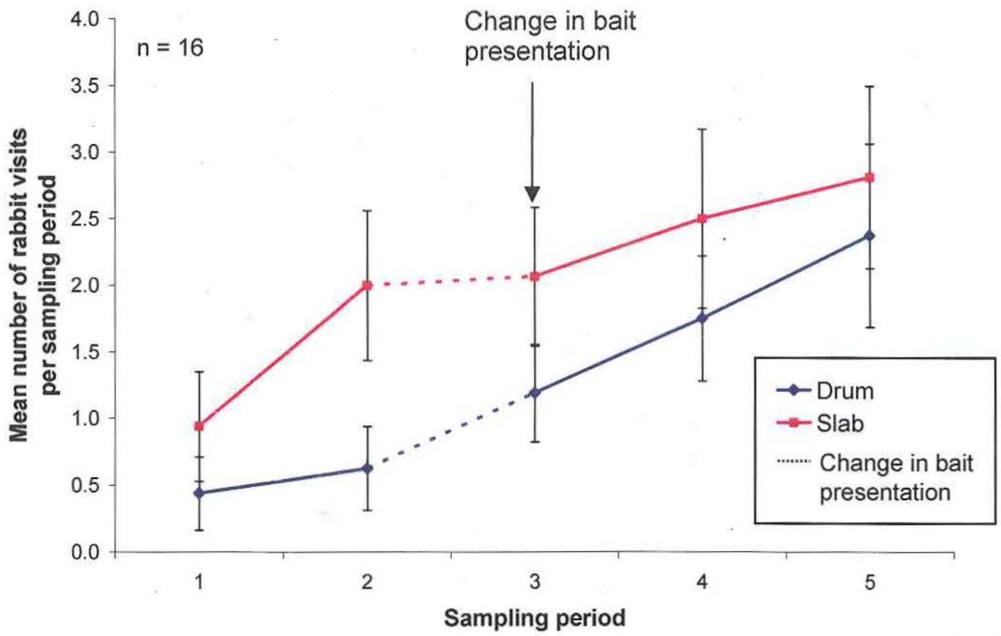

Figure 4.4 Mean number of rabbit visits (± 1 S.E.) to the two different bait station designs over five sampling periods. Sampling period one and two differ from sampling periods three to five in the way the bait was presented (illustrated by the dotted line between sampling period two and three). Values are means from 16 bait stations.

Table 4.3 Results of the Mann-Whitney U test analysing rabbit visitation to the different bait station designs per sampling period. The table shows the mean (± 1 S.E.) number of rabbit visits, the Z value and the two-tailed significance level. * = significant at the $p < 0.05$ level.

Sampling period	Bait station	Mean ± 1 S.E.	Z	p
1	Drum	0.4 ± 0.27	-0.89	0.372
	Slab	0.9 ± 0.41		
2	Drum	0.6 ± 0.31	-2.30	**0.022***
	Slab	2.0 ± 0.56		
3	Drum	1.2 ± 0.37	-1.30	0.196
	Slab	2.2 ± 0.5		
4	Drum	1.8 ± 0.47	-0.54	0.586
	Slab	2.5 ± 0.67		
5	Drum	2.4 ± 0.69	-0.43	0.667
	Slab	2.8 ± 0.68		

4.3.3. Analysis of bird visits

The number of bird visits to the two bait station designs was not significantly different for sampling period one (Table 4.4) but was for sampling period two (Table 4.4), with more birds visiting the slabs than the drums (Table 4.4, Figure 4.5).

After the bait presentation was changed, sampling period three showed a no significant difference between the number of visits to drum and slab designs by birds (Table 4.4). However, this is only slightly over the 0.05 significance level. The last two sampling periods show a significant difference between the numbers of bird visits to the bait stations (Table 4.4), with more birds visiting the slabs than the drums. The change of bait presentation had a clear impact on bird visits with visits to both slabs and drums falling (Figure 4.5).

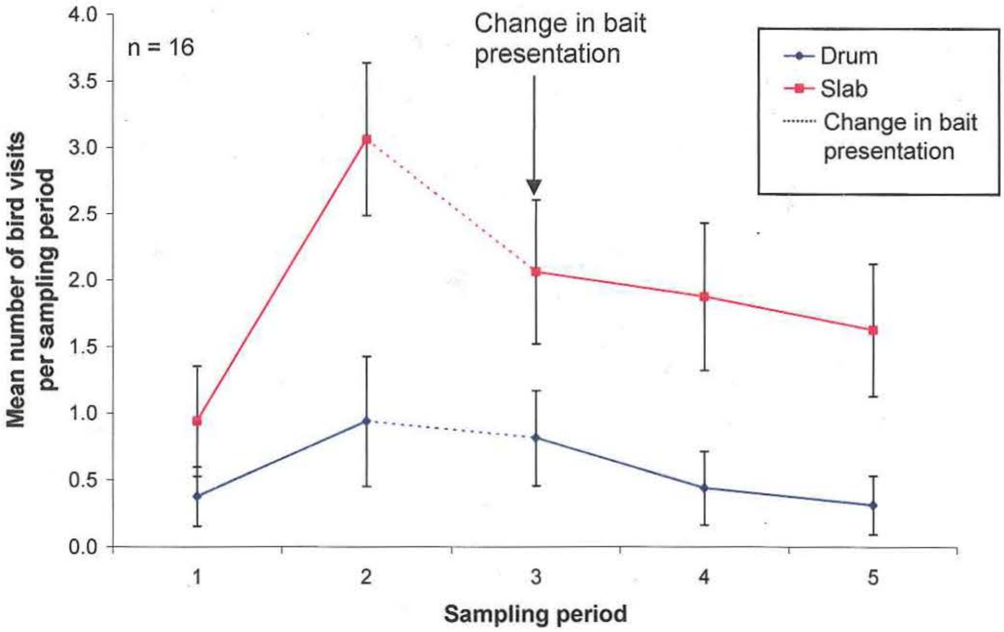

Figure 4.5 Mean number of bird visits (± 1 S.E.) to the two different bait station designs over five sampling periods. Sampling period one and two differ from sampling periods three to five in the way the bait was presented (illustrated by the dotted line between sampling period two and three). Values are means from 16 bait stations.

Table 4.4 Results of the Mann-Whitney U test analysing bird visitation to the different bait station designs per sampling period. The table shows the mean (± 1 S.E.) number of rabbit visits, the Z value and the two-tailed significance level. * = significant at the $p < 0.5$ level.

Sampling period	Bait station	Mean ± 1 S.E.	Z	p
1	Drum	0.4 ± 0.22	-1.17	0.244
	Slab	0.9 ± 0.41		
2	Drum	0.9 ± 0.49	-2.84	**0.004***
	Slab	3.1 ± 0.57		
3	Drum	0.8 ± 0.36	-1.84	0.065
	Slab	2.1 ± 0.54		
4	Drum	0.4 ± 0.27	-2.46	**0.014***
	Slab	1.9 ± 0.55		
5	Drum	0.3 ± 0.22	-2.28	**0.023***
	Slab	1.6 ± 0.50		

4.3.4. Analysis of rodent visits

The numbers of rodent visits to the bait stations were significantly different during sampling two (Table 4.5) and sampling four (Table 4.5), with more rodents visiting the drums. The other three sampling periods were not significantly different (Table 4.5) although rodents were always visiting the drum designs more than the slab designs (Figure 4.6). Figure 4.6 also shows that the number of rodent visits was declining after the change of bait presentation was made.

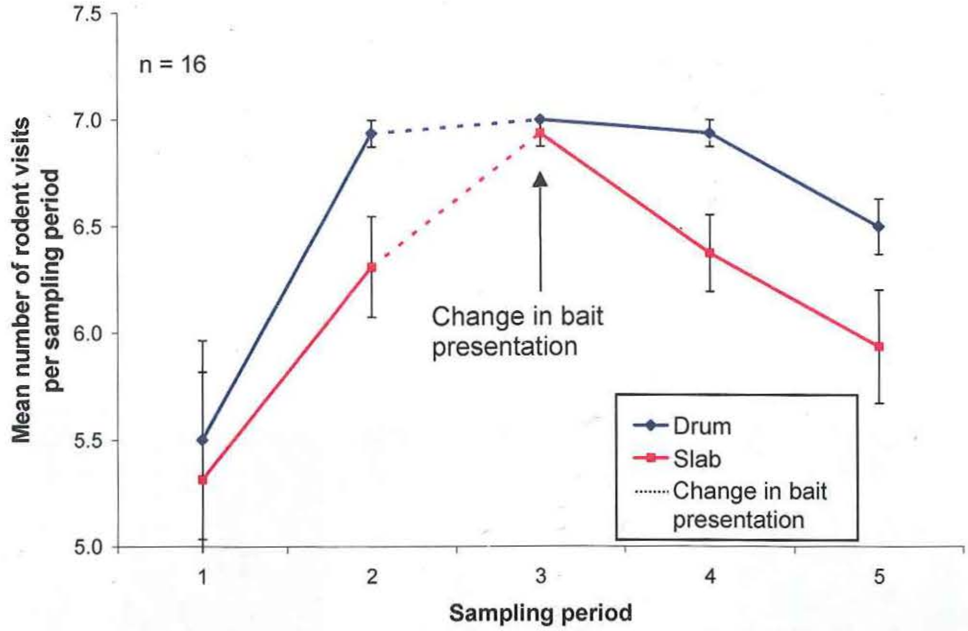

Figure 4.6 Mean number of rodent visits (± 1 S.E.) to the two different bait station designs over five sampling periods. Sampling period one and two differ from sampling periods three to five in the way the bait was presented (illustrated by the dotted line between sampling period two and three). Values are means from 16 bait stations.

Table 4.5 Results of the Mann-Whitney U test analysing rodent visitation to the different bait station designs per sampling period. The table shows the mean (± 1 S.E.) number of rabbit visits, the Z value and the two-tailed significance level. * = significant at the $p < 0.05$ level.

Sampling period	Bait station	Mean ± S.E.	Z	p
1	Drum	5.5 ± 0.47	-0.22	0.829
	Slab	5.3 ± 0.51		
2	Drum	6.9 ± 0.06	-2.46	**0.014***
	Slab	6.3 ± 0.24		
3	Drum	7.0 ± 0.00	-1.0	0.317
	Slab	6.9 ± 0.06		
4	Drum	6.9 ± 0.06	-2.73	**0.006***
	Slab	6.4 ± 0.18		
5	Drum	6.5 ± 0.13	-1.66	0.098
	Slab	5.9 ± 0.27		

4.3.5. Footprint analysis

The identification of animal footprints proved to be much more difficult than anticipated and required careful and systematic observations of prints during the first months of the experiment. At the start of the study the sand at the bait stations was very dry due to good weather conditions so that footprints left behind by animals visiting the bait stations did not stay clear (Plate 4.5) This made it hard to identify visiting animals.

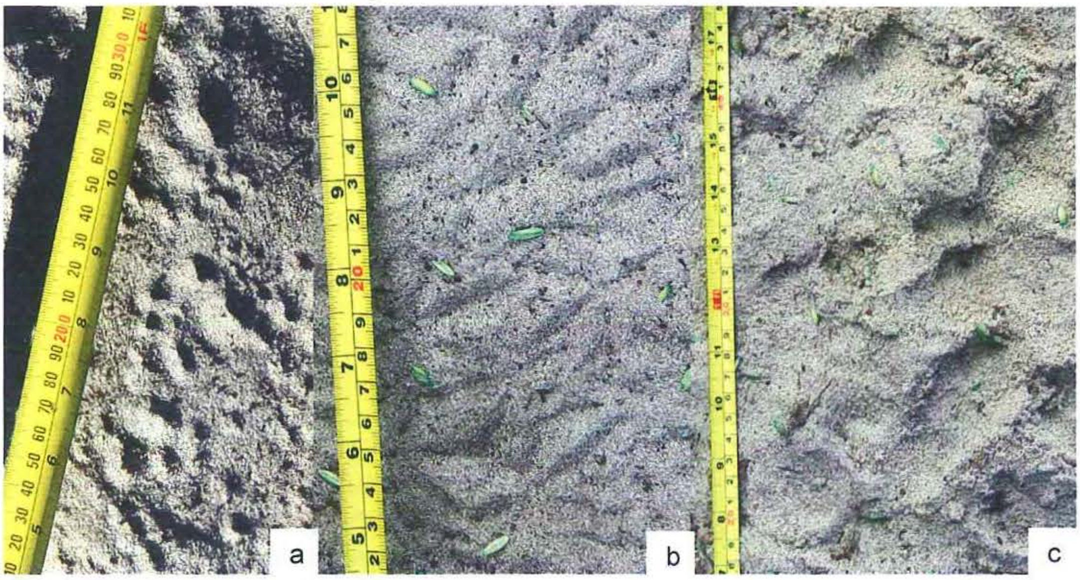

Plate 4.5 Unclear footprints of a rodent (a), bird (b) and rabbit (c). Tape measure for scale (Photos: Malin Kordes, 2004).

In general, animal footprints were sorted into four categories: bird, rodent, lizard and rabbit (Table 4.6). Lizard tracks were only found during the first sampling period and were therefore not considered further. They were therefore taken out of the analysis. Later in the study, good footprints were obtained due to the sand being moist but not saturated (Plate 4.6).

Table 4.6 Non-target species visiting the bait stations. The table shows species identified to visit bait stations and species that have been observed nearby and could take bait from the bait stations.

	Birds	Rodents	Lizards	Invertebrates
Identified species	Australian magpie (*Gymnorhina tibicen*) Australian raven (*Corvus coronoides*) Laughing turtle dove (*Streptopelia senegalensis*) Spotted turtle dove (*Streptopelia chinensis*) Painted button-quail (*Turnix varia*)	House mouse (*Mus musculus*) Black rat (*Rattus rattus*)	Lizard sp.	Spider sp. Beetle sp. Ant sp. Cockroach sp. Millipede sp. Sandgroper sp. Earwig sp.
Seen nearby	Willie wagtail (*Rhipidura leucophrys*) Australian ringneck (*Barnardius zonarius*) Rainbow lorikeet (*Trichoglossus haematodus*)			

Plate 4.6 Good tracks of a) rodent paw, b) front paws of a rabbit, c) slow moving rabbit including 2 rabbit pellets and d) raven. Tape measure for scale (Photos: Malin Kordes, 2004).

4.3.6. Summary of the main findings

The major finding of the field experiment are summarised below:

- Bait take at the slab designs was significantly greater than at the drum designs.
- Some temporal differences in bait uptake were observed.
- Overall, rabbits showed a preference for the slab design; however, significantly different results were obtained only for sampling period two.
- Rabbit visits to both bait station designs increased over time.
- Birds showed a preference for the slab design.
- Restricting the access to bait from sampling period three onwards resulted in fewer bird visits to both bait station designs over time.
- Rodents showed a preference for the drum design.
- Restricting the access to bait from sampling period three onwards resulted in fewer rodent visits to both bait stations over time.
- Identification of footprints under field conditions can be difficult.

4.4. *Discussion*

4.4.1. Acceptability of bait stations by rabbits

The analysis of rabbit visits to the two bait station designs showed that rabbits readily accepted both the slab and the drum designs. Although only sampling period two showed a significant difference between rabbit visits to the slab and drum designs, rabbits always visited the slab designs more than the drum designs. This confirmed the outcome of Twigg *et al.* (2001, 2002a) who investigated the acceptability of four different bait stations to rabbits in an urban setting. They found that the slab design was more acceptable to rabbits than the drum design, but that rabbit visits to drums increased when compared to a 'tyre' design (a tyre on bricks under a corrugated iron sheet). This suggests that rabbits readily accept bait stations and feed from them.

4.4.2. Bait uptake

The analysis of the amount of bait taken at the different bait station designs over time showed that animals were always taking more bait from the slab design than from the drum design. When analysing the bait uptake according to the animal(s) visiting the bait stations (Figure 4.7), it becomes apparent that rodents are taking the greater percentage of the bait. Over time, the amount of bait consumed was less for rodents alone but more for rodents and rabbits combined. However, as rodent visits to the stations decreased, this increase is due to rabbit take. Also, the increase of bait uptake at the slabs by birds and rodents & birds during sampling period two was not due to bait being taken but to large spillages caused by birds.

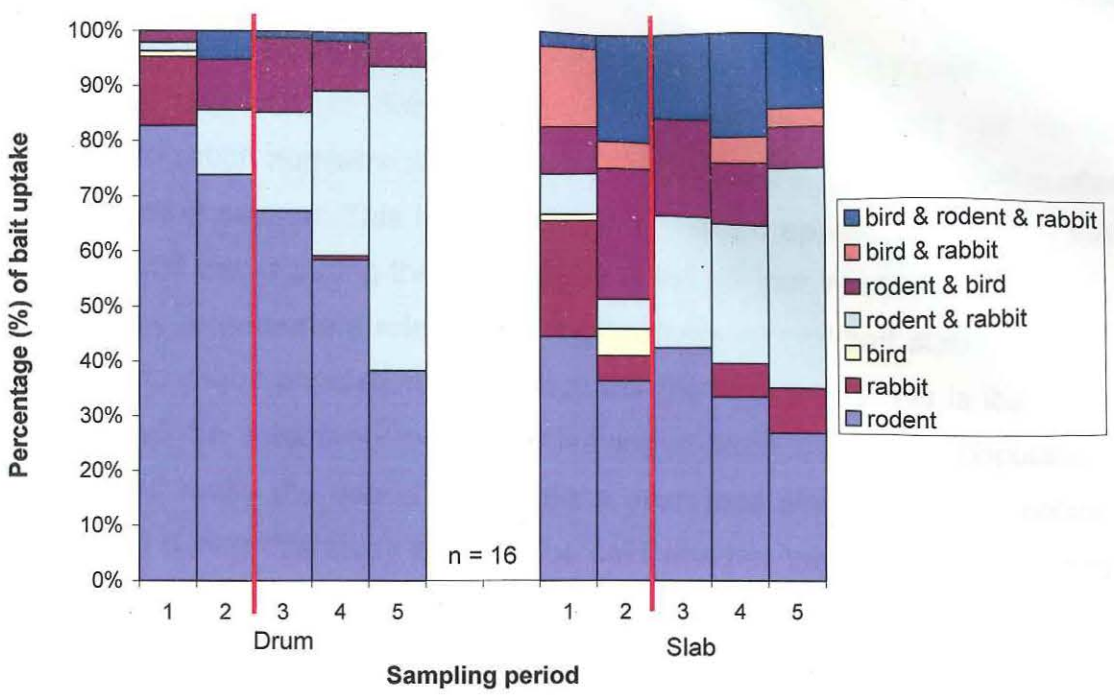

Figure 4.7 Changes in the percentage (%) of bait uptake by animals at the two bait station designs over all sampling periods. Sampling period one and two differ from sampling periods three to five in the way the bait was presented (illustrated by the red line between sampling period two and three).

4.4.3. Efficacy of bait stations for rabbit control

As no poison was used during this study it could not be investigated whether the use of bait stations would result in a reduction of rabbit numbers to an acceptable level. Twigg *et al.* (2001, 2002a), who investigated the efficacy of bait stations, showed that the use of bait stations during an actual poisoning program usually resulted in highly variable kill rates (0-80% over 30-60 days for pindone presented in bait stations, Twigg *et al.*, 2001). Neophobia ("the avoidance of an unfamiliar object in a familiar place", Oliver *et al.*, 1982, p. 132) in rabbits is one possible explanation for the variability in kill rates when bait stations are used (Twigg *et al.*, 2002a). Twigg *et al.* (2002a) observed that rabbits were feeding from the stations during the free-feed periods. However, as soon as these were killed (when poison was placed into the stations), no new rabbits visited the stations. A study conducted in New Zealand on the bait uptake by rabbits from modified bait stations used for possum control found a similar response, with only some rabbits accepting the bait stations (Brown, 2002).

During the present study rabbit visits to the stations increased over time. This however may not be due to reduced neophobia over time but to the increased rabbit numbers due to young rabbits entering the population after the breeding season. This is supported by frequent appearances of smaller sized rabbit tracks during the later stages of the project. However, neophobia could play an important role in the long-term efficacy of bait stations if only part of the rabbit population feeds from the bait stations. If this is the case, rabbits will be selectively poisoned, leaving a more neophobic population. This could make the use of bait stations even less effective. As no poison was used during this study it cannot be said whether the rabbit population is highly neophobic or not. Neither can it be said whether the use of bait stations during a pindone poisoning program would be totally effective in reducing the number of rabbits to an acceptable level.

Another reason why bait stations might not be utilised by rabbits is that sufficient food is available in the area. This could have been a factor during this study, as it was conducted during autumn and winter, when sufficient green feed was available for animals. However, Brown (2002) found that rabbits did not consume less bait at stations where vegetation was abundant than at stations where food was scarce within 3 m of the bait station. He therefore concluded that the abundance of greenstock is an unlikely factor for why rabbits are not utilising bait stations.

Reduced effectiveness of poison programs can also be due to rabbits becoming resistant to the poison used (Twigg *et al.*, 2002b). Rabbits can develop resistance when they ingest sublethal doses of a given poison. This could be due to the bait losing its effective ingredient or to specific behaviour by the target animal that reduced the amount of poison being ingested (Twigg *et al.*, 2003a). Twigg *et al.* (2003a) reported that a high proportion of rabbits (at 80-88% of feeding stations) were de-husking the oat seeds used as bait. This substantially reduces the amount of poison ingested, as most of the poison impregnated into an individual oat seed is found within the husk (~80%; ACT, 2003; Twigg *et al.* 2003a). Whether this would have any serious implications on the use of pindone is not known. In Bold Park, rabbits were

not seen to de-husk the oat seeds (pers. obs.). If any poisoning program were to be implemented in Bold Park, this behaviour should be monitored.

The development of shyness to bait and/or the poison might also present problems for a control program using poison. Bait shyness is believed to be partly due to conditioned food aversions (CFA), which are caused through animals learning that a particular food causes illness. Subsequently they then avoid the food. As bait stations have to be active for relatively long periods of time to be effective, the risk of rabbits developing a CFA increases (Twigg *et al.*, 2001).

If any of the above mentioned factors are present or develop within the rabbit population of Bold Park, rabbits would be selectively killed, making poison more and more ineffective. It is therefore recommended that control methods be used alternately or combined to reduce the risk of selective killing (Oliver *et al.*, 1982).

4.4.4. Acceptability of bait stations by non-target animals and primary poisoning risk

Birds

Bird species were the primary focus for non-target species visiting the bait stations because they are known to feed on bait laid in a trail as well as from bait stations (Martin *et al.*, 1994; Twigg *et al.*, 2001). Other mammals were of lesser concern, as the Common brushtail possum and two species of bats (the only native mammals in Bold Park (How, *et al.*, 1996; Ninox Wildlife Consulting, 1999)), were not expected to be attracted by the bait, were the only native mammals recorded in Bold Park (. This study showed that birds are feeding from both bait station designs. However, the drum design was visited less by birds than the slab design. Twigg *et al.* (2001) reported similar results in an urban area but no details about these visits were given.

Bird visits during this study showed a pattern of birds frequently returning to the bait stations once the bait was found. It cannot be said whether the same

bird or group of birds returned every time or whether different birds were visiting on different days. However, from the observations made, it seems to be more likely that the same bird(s) returned every time and if this occurs, these birds would be more at risk of ingesting a lethal dose of poison.

Martin *et al.* (1994) investigated whether five Australian bird species would be at risk of being poisoned by pindone. They found that the sensitivity to pindone varied among bird species, which makes it hard to extrapolate the risk from one bird to another. The only species that was feeding from the bait stations during this study and that was investigated by Martin *et al.* (1994) was the Australian magpie. Magpies are omnivorous and therefore it would be unlikely that they ingest a lethal dose of pindone by feeding on bait (Martin *et al.*, 1994; Simpson & Day, 1999). However, in this study and Martin *et al.*'s study (1994) they were observed to feed on pindone trails for extensive periods of time during which they ingested a substantial amount of grain. Magpies have a variable response to pindone, with two of the birds tested by Martin *et al.* (1994) showing almost no response, while another showed a considerable response to the poison. This variability in response to pindone and the possibility of ingesting large amount of bait puts magpies in general at a considerable risk of being poisoned by pindone. On the other hand, some magpies were observed to de-husk grain before consumption, a behaviour that greatly reduces the amount of poison ingested (Martin *et al.*, 1994). As discussed earlier, this is because most of the poison is situated in and on the husk (Martin *et al.*, 1994; ACT, 2003; Twigg, 2003a).

As no data were available regarding the sensitivity of the other birds observed at or near the bait stations, the risk of poisoning to these can only be estimated. Ravens would probably not be at high risk, as they are omnivorous (Schodde & Tidemann, 1986; Simpson & Day, 1999) like magpies and some of them were observed to de-husk the oat seeds. However, just like the magpies, ravens could take the opportunity of the readily available food and thus increase the risk of poisoning.

Painted button-quails were not observed to feed on the bait during this study, although their tracks were next to the saucer containing the bait. This

suggests that they may feed from the bait. Quails are as much granivorous as insectivorous (Schodde & Tidemann, 1986; Simpson & Day, 1999), suggesting that they could be at risk of being poisoned. Both dove species (Laughing turtle-dove, Spotted-neck turtle-dove) observed at the stations would probably be at a high risk of ingesting a lethal dose of pindone as they did not de-husk the oat seeds and their diet consists mainly of seeds (Schodde & Tidemann, 1986; Simpson & Day, 1999). According to the Bold Park Management Plan (2000) the only other dove known to occur within Bold Park, but which was not seen at the bait stations, is the Rock or Feral dove (*Columba livia*). This dove has the potential to find the bait and feed from it, which would put it at risk of being poisoned. However, all three dove species are not native to Western Australia, so poisoning of these birds might be acceptable to management. Nevertheless, the public would most likely be opposed to poisoning these doves, particularly the two turtle-doves, as they are very common and visible.

Other birds that were seen in the vicinity but not at the stations included the Australian ringneck parrot, Willie wagtails and Rainbow lorikeets. Birds that have been observed by Twigg *et al.* (2001) in an urban setting were Australian ringneck parrots, magpies, Crested pigeons, Common bronzewings, magpie-larks and ravens. Australian ringnecks have been classified to be slightly at risk of being poisoned because they are sensitive to pindone. However, Martin *et al.* (1994) said that Australian Ringnecks are able to reduce the risk by firstly roosting when they are unwell and secondly because they de-husk the oat seeds before consumption (Martin *et al.*, 1994). Willy wagtails and Rainbow Lorikeets would possibly not be at risk or only very slightly, as they feed on insects and nectar and pollen, respectively (Schodde & Tidemann, 1986; Simpson & Day, 1999).

During an actual baiting program the risk to birds depends on the bird species present at the time of baiting, their diet and their behaviour (Martin *et al.*, 1994). However, this and Twigg *et al.*'s study (2001) showed that the use of drum bait stations reduces bird visits and hence bait uptake. Also, during this study, all bird species were found at the slab designs, while only the doves were regular visitors to the drum design, with the occasional visit by a

raven or magpie. Although the accessibility of bait can be restricted for birds, bait would have to be present in the field for a considerable amount of time (Twigg *et al.*, 2001; Twigg *et al.*, 2002a). As a result, birds could become accustomed to the presence of readily available food and feed from the bait on a regular basis, therefore increasing the amount of poison they ingest. The possibility of birds becoming used to a readily available food source can be reduced by making bait inaccessible during the day. This study clearly showed that the number of visits to both stations decreased as soon as the bait was covered during the day.

Rodents

Rodents are known to take oat bait used for rabbit control (e.g. Brunner, 1983). The analysis of rodent visits to the bait stations showed that rodents preferred the drum design. They even constructed entrances to their burrows underneath them. Rodents would certainly be at risk of being poisoned, as pindone is a known rodenticide (poison for rodent) and kills rodents when presented in a 0.25 g/kg mix (Saunders *et al.*, 1955). During this study rodents were taking most of the bait (Figure 4.7). However, rodents, like some birds, were de-husking the oat seeds before consumption. They also did not eat the whole kernel (see Appendix F, Plate 13.2a), further reducing the amount of poison ingested. This could result in insufficient poison being ingested to actually kill the rodent. This can have the consequence of a) the development of bait shyness (avoidance of bait because it causes illness) and/or b) the development of resistance over time. The fact that rodents develop a resistance to anticoagulants is well known (e.g. Redfern & Gill, 1980; Cowan *et al.*, 1995) and if this occurs for pindone, rodent populations within the baited area could increase rapidly as rodents usually breed whenever food is available and the conditions are favourable (Watts & Aslin, 1981; Menkhorst & Knight, 2001).

It was also observed that rodents cached oat seeds to locations up to 1.5 m away from the stations (see Appendix F, Plate 13.2b). Most of the oat kernels were consumed at these locations but the husks were left behind. As most of the poison is contained on and within the husk (ACT, 2003) of the bait, these

piles of husks might pose a threat to other animals that feed on them. During the study, no animals were observed doing so, but if a poisoning program is conducted during summer when food abundance is low, some animals might utilise the husks as a food source.

Native mammals

Native mammals such as kangaroos or bandicoots are sensitive to pindone but the risk to these can be minimised by carefully assessing the situation and applying precautious measures such as laying the bait away from the habitat of these animals (e.g. Brunner, 1983; Hartley *et al.*, 1999; Stafford & Best, 1999; Moro, 2001). As only brushtail possums and bats are present within Bold Park (How, *et al.*, 1996; Ninox Wildlife Consulting, 1999), no special precautions are required to accommodate for their safety.

Reptiles

Lizard tracks were observed during the first sampling period but these could not be analysed because no lizard tracks were found in the subsequent sampling periods. Most lizards hibernate during winter month to avoid the cold temperatures (Bustard, 1970; Heatwole & Taylor, 1987) and as this study was conducted during winter, lizard sightings were not expected. However, as the best time for poisoning rabbits is during late summer (DoA, 2001a) when lizards are active, lizards could be another group of non-target species that might be affected by a pindone poisoning program. According to internal communication (Bold Park) it is likely that some bobtails will be poisoned but that this would not have a long-term effect on the population. Whether other lizards would be at risk of being poisoned and whether this would have a long-term effect upon the population cannot be said as no information was found on the toxicity of pindone to lizards. No information was found for snakes. It seems likely though, that if snakes ingest poisoned rodents or other prey, that this would have an effect on the snakes.

Invertebrates

Invertebrate species observed at the stations (Table 4.6) were mostly using the stations as shelter but only ants were observed eating the oat seeds. They carried small sections of oat seeds which had been left behind by rodents. Pindone has been found to have insecticidal properties (Kilgore *et al.*, 1942). However, no information was found in the literature on whether insects need to ingest the poison or whether contact is sufficient to kill. Nevertheless, a study conducted in New Zealand on the identity and abundance of invertebrates feeding on four different bait types used for aerial possum and rodent control (Spurr & Drew, 1999) found that, even if invertebrates were at risk, a poison program would probably not have a lasting negative effect on invertebrate populations. This might vary from location to location as the composition of the invertebrate fauna differs. It is therefore recommended that, if a poisoning program should be implemented, its impact on the arthropod fauna should be monitored.

4.4.5. Secondary poisoning risk

Secondary poisoning of non-target animals occurs when an animal ingests material from a poisoned animal (Williams *et al.*, 1995). There are a range of animals in Bold Park that could be at risk of being poisoned by eating a poisoned rabbit for example. Species at risk would be domestic and feral cats and dogs, foxes and birds of prey, as they regularly feed on small mammals. Also at risk would be birds like ravens, magpies and butcherbirds that are omnivorous as well as partial scavengers (Simpson & Day, 1999).

The general risk of secondary poisoning by ingesting poisoned rabbits during a rabbit control program is reduced as rabbits tend to die underground and the few rabbits that die above ground are usually found under dense scrub (Twigg *et al.* 2003b). Rodent and other small mammal carcasses are usually hard to find as well (Brunner, 1983). Also, carcasses usually degrade reasonably quickly. During Twigg *et al.*'s study (2003b) rabbit carcasses degraded within approximately two weeks and rodent carcasses decayed within six days. The NRA Review of pindone (2002) states that preliminary results by Animal Control Technologies have indicated that pindone

disintegrates slowly within dead rabbits. No data is available on actual residue levels but the NRA (2002) reports that maximum levels are likely to be within the range of 10-50 mg/kg. This in turn would put consumers of rabbit carcasses and possibly rodent carcasses at risk of being poisoned. Also, predators would be likely to take live animals that have not yet died (NRA, 2002). These animals could have relatively large amounts of pindone within their bodies and if these are ingested over consecutive days it could put the predator at risk of being poisoned.

Dogs

Beauregard *et al.* (1955) carried out studies on dogs, finding that pindone is much less toxic if administered in a single large dose (lethal dose = 75 to 100 mg per kg) than in small daily doses (lethal dose ~ 15 to 35 mg per kg, daily dose = 2.5 mg). A more recent study by Martin *et al.* (1991) reports that no clinical signs of pindone poisoning have been observed in dogs despite an increase in blood clotting times. Beauregard *et al.* (1955) also showed that vitamin K_1 is an effective antidote. Most dogs in urban parks and reserves are pets that are exercised by their owners and in Bold Park for example it is required that dogs be kept on leads (BGPA, 2000). Under these conditions dogs would be relatively safe from secondary poisoning. Unfortunately, in many reserves and parks most dogs are not kept on a lead, and such dogs roam freely (pres. obs). If it is assumed that 50 mg/kg (NRA, 2002) of pindone is found in dead rabbits than the poisoning risk would be low for a dog that ingests one rabbit carcass. The risk to dogs being poisoned by eating poisoned rabbit carcasses on consecutive days would be larger. However, it would also be less likely that a dog would consume carcasses on consecutive days, an assumption based on the fact that very few incidences have been reported (NRA, 2002). This risk could be further reduced through extensive education and information campaigns. Jackson (2003) for example showed that if park users are appropriately informed about control programs the owners of dogs seem to be more responsible and keep their dogs on the lead.

Cats

Beauregard *et al.* (1955) also carried out a limited study on the effect of pindone on cats and suggested that cats would be only slightly at risk of being poisoned by pindone under field conditions. Under laboratory conditions though, Martin *et al.* (1991) found that cats were one of the most susceptible animals to pindone. Although no further studies about the impact of pindone on cats were found, the risk to cats (and dogs) is frequently mentioned on information sheets about rodent control (e.g. Whisson, 1996). It is therefore likely that cats are at risk of being poisoned by pindone.

Birds

The risk to birds that feed or might feed on poisoned rabbits and/or rodents depends on the sensitivity of the individual bird to pindone and the amount of pindone ingested. Martin *et al.* (1994) investigated the effect of pindone on wedge-tail eagles and found that they are at moderate to high risk of being poisoned. Other raptors might be at risk of being poisoned but no definite risk assessment can be made from the available data. Nevertheless, few incidences have been reported during baiting programs, indicating that the actual risk in the field might be relatively low (NRA, 2002).

4.4.6. Methods to reduce bait uptake by non-target species

This study demonstrated that reducing the amount of bait available to non-target species can by achieved by covering or removing the bait during the day. Another tactic would be to estimate the uptake per night through free-feed periods and then loading bait stations at dusk with an amount of bait that is just below the amount taken during the free-feed period. This ensures that rabbits are taking the bait and non-target species will not get to it. However, this might reduce the effectiveness of a baiting program, as dominant rabbits might exclude subordinate rabbits from feeding from the bait (NRA, 2002). It also does not accommodate rabbits that are active during the day. In Bold Park fresh rabbit tracks have been observed in the afternoon, when the bait stations were set for the night. This indicates that at

least part of the population might be active during the day, which would reduce the effectiveness of a poisoning program even further.

Another way of reducing the accessibility of bait to non-target species would be to use a different type of bait station. A recent study conducted in New Zealand by Isaac *et al.* (2004) investigated whether automated feeders could be used for food-supplementation studies with possums. These feeding stations released a certain amount of food according to the animal's weight. If the basic design of these feeding stations could be altered and possibly simplified to suit rabbit control, they could be a valuable tool in reducing the risk to non-target animals. Whether rabbits would readily accept and feed from these stations and whether control of rabbit numbers would be effective is unknown.

Using a different type of bait could also reduce the amount of bait taken by non-target animals. Brunner (1983), for example, investigated the uptake of pellets, oat seeds and carrots by target and non-target mammals. He found that carrots were most acceptable to rabbits and least acceptable to rodents like the House mouse and Black rat. Oat seeds however, were accepted by rabbits but even more so by rodents. Whether this would be the case in Bold Park and whether carrot bait would attract a different array of non-target animals was beyond the scope of this study and would need to be tested. One disadvantage of carrot bait is that a ready-to-use mix is only available from the Department of Natural Resources And Environment, Victoria (NRA, 2002). The bait can be prepared using chopped carrot and adding either a concentrated powder or liquid form of pindone. However, this product is only supplied to government agencies and licensed contractors. Carrot baits are also more expensive than oat seeds (NRA, 2000).

The removal of all bait and as many carcasses as possible would reduce the primary poisoning risk to non-target animals and the secondary poisoning risk to predators and scavengers (NRA, 2002). This is very time and resource intensive but would prove viable if secondary poisoning was found to be a problem.

4.4.7. Identification of tracks

The identification of animals using sand plots can be unreliable, particularly during adverse weather conditions and when the observer is inexperienced in reading tracks of target and non-target animals (Glen & Dickman, 2003). The initial difficulties of identifying tracks during this study were mostly due to both unfavourable weather conditions and inexperience. Also, when animals visited the bait stations they were often moving around, so that tracks overlapped (pers. obs.), making it hard to identify a print. In addition, different animals were visiting the bait stations at different times and again, tracks overlapped or were erased completely. This particular case was observed during the last three sampling periods in dry sand under drums. Occasionally rabbit tracks were observed under drums when the bait was uncovered in the late afternoon. To test whether the track would still be visible the next morning the sand around the track was smoothed out but the track was not erased. When the same bait station was checked the next morning the track was not visible anymore because it had been wiped out by groups of rodent footprints. This could have had an impact on the animal count, with number of visits to the stations being underestimated. In particular, this would have occurred at dry sand plots where either high numbers of rodents were visiting or rodents were frequently moving around the bait. Whether birds and rabbits would wipe out other tracks through their activity cannot be said as this was not observed.

A more accurate way of identifying animals visiting the bait stations would be to take photographs or film visiting animals, as this is a much more reliable method than sand plots. This would also allow for the identification of individuals, which can help in the assessment of the efficacy of bait stations (Glen & Dickman, 2003). For example, it could have been that only one rabbit visited two nearby stations. It was initially planned to monitor the more frequently visited bait stations with a video surveillance system (Faunatech Series) to assist with the identification of animals visiting the bait stations. Unfortunately, the equipment was not in working condition so that the identification of animals had to rely on the sand plots alone. Despite the inaccuracy of sand plots, it is believed that all animals that visited the bait stations during this study have been identified correctly.

5. SYNTHESIS

The European rabbit poses a significant risk to the persistence of the flora and fauna in Australia. It is therefore necessary to control rabbit populations in order to protect the Australian environment. The need for rabbit control is acknowledged in the legislation of all Australian states and territories (Williams *et al.*, 1995). In urban areas though, rabbit control is not carried out as easily as in rural areas due to public health concerns. Pindone is the only recognised poison for use in an urban area (Robinson, 1990; Twigg, 2001). However, little information about pindone is available in the literature. Also, little research has been conducted concerning rabbit control with pindone in public reserves and parks.

5.1. The questions answered

This research provided the opportunity to test the use of bait stations for rabbit control in an urban bushland reserve that is open to the public. This study answered a number of research questions, which have contributed to the knowledge about whether rabbits will feed from bait stations and what kinds of non-target species are at risk of being poisoned. These research questions and the outcomes of the study are outlined below.

1. *Do rabbits take bait from the two bait station designs? If so, do they show a preference towards feeding from one of the two bait station designs?*

The results from this study demonstrated that at least part of the rabbit population accepts and feeds from bait stations. In other studies it was found that the use of bait station results in highly variable kill rates (Twigg *et al.*, 2001). Whether this would be the case in Bold Park cannot be said as no poison was used during this study. The distribution of visits showed that rabbits always visited the slab design more frequently than the drum design. However, this difference decreased over time and was only significantly for sampling period 2.

2. *Are the bait stations being visited by non-target species? If so, which species are visiting the bait stations?*

A number of non-target species visiting the bait stations were identified through the analysis of footprints, observation of animals and identification of scats. Species identified were: Australian magpies, Australian ravens, doves, Painted button-quails, Black rats and House mice. Birds were usually seen at the stations during the day, while rodents seemed to be active both night and day.

3. *If non-target species are visiting the bait stations, which bait station design has the least number of visits by non-target species?*

Birds visit the slab design more often than the drum design. The only regular visitors to the drum bait stations were the doves, while raven and magpie footprints were occasionally observed at the drums. Therefore drums would be best to use when birds are of major concern during a baiting program.

Rodents preferred the drum bait stations over the slab bait stations. Rodents even constructed entrances to their burrows underneath some of the drums.

Strategies to restrict access to bait, such as covering the bait during the day, can be effective in reducing the risk of poisoning to non-target animals.

4. *Do the oat seeds used as bait germinate?*

The germination and potting trials conducted during this study confirmed that the oat seeds used as bait are not able to develop into fully grown oat plants. The use of these oat seeds would therefore not add to the weed problem within Bold Park.

5.2. *Limitations of the project*

The major limitations of this research were: a) research was only undertaken in one urban bushland, which limits the application of outcomes to other urban bushlands; b) due to time restrictions this study was carried out over the autumn/winter period, which might have had implications on the species visiting the bait stations; c) some warrens were in close proximity to each other, meaning that one rabbit could have visited more than one bait station at any one time; and d) due to multiple animals visiting the bait between set up and inspection of the bait stations, some of the footprints could have been eradicated, which may have led to an underestimation of the number of visits by animals.

5.3. *Research recommendations*

Rabbit control is an ongoing process and research for new control methods continues. Most of the control methods specifically target rabbits. For example, the rabbit calicivirus only targets the European rabbit and no other species. Unfortunately, these methods are not very effective in reducing rabbit numbers or cannot be used under certain conditions (e.g. Williams *et al.*, 1995; DoA, 2003). In general, poisoning with 1080 and pindone is the most effective and cheapest method to control rabbit populations. However, these poisons are not species-specific and can pose a substantial risk to non-target animals. As it is unlikely that the rabbit problem will be solved quickly, poison will remain the number one choice for rabbit control. This may have unwanted effects on the native fauna unless access to bait by non-target animals is restricted.

With regards to the use of pindone there are gaps in the knowledge of the effect of pindone on animal species. Further research should therefore be directed at:

1. Determining the risk of pindone to possible non-target animals under field conditions.
2. Investigating ways of restricting access to bait by non-target animals (e.g. automated feeders specifically administering bait to target animals).

3. Testing whether the findings of this study apply to other urban bushland reserves.

5.4. Management recommendations

This study demonstrated that at least part of the rabbit population in Bold Park accepts and feeds from both the drum and slab bait station designs. However, several factors such as neophobia, resistance to pindone and bait shyness in rabbits might influence the efficacy of poisoning and needs to be considered. The results of this research also indicate that the use of bait stations would be beneficial for a poisoning program in terms of reducing the poisoning risk to non-target animals.

Following from the results of this research, the following management recommendations are made:

1. Before the implementation of any poisoning program, it is essential that the public be informed about the reason why it is implemented and what the possible consequences are. This can be accomplished by newspaper announcements, workshops, signage, various information brochures and letterbox drops (for a draft of an information brochure see Appendix G).
2. If a baiting program is initiated, the use of bait stations similar to the drum design is recommended to reduce the risk of non-target animals being poisoned.
3. Bait stations should be monitored for non-target animals that were not present during this study (e.g. lizards).
4. The efficacy of any baiting program in Bold Park should be assessed.
5. During the baiting program the rabbit population should be monitored for the occurrence and/or development of neophobia, resistance to bait and bait shyness.
6. Insect populations should be monitored to assess the effect of pindone on these populations.
7. Access to bait should be restricted during the day if possible, to reduce the risk to non-target species.

8. The use of carrots instead of oat seeds as bait should be considered as carrots are less attractive to birds.
9. If oat bait is used, the oat seeds need to be sterilised to prevent germination.
10. Any carcasses (rabbit, rodent or bird) should be removed if possible.
11. Poisoning should be complemented by other control methods (e.g. warren fumigation).

Bold Park is one of the largest bushland reserves remaining on the Swan Coastal Plain. If feral animals like rabbits and foxes could be kept at very low levels or, even better, could be eradicated from Bold Park, there may be hope not only for the persistence of the vegetation and the remaining native fauna but also that native animal species could be re-introduced. This might be a goal worthy of attention as part of the new management plan due to be released in 2005.

6. REFERENCES

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7. APPENDICES

Appendix A

Germination trial raw data

This Appendix gives an example of the data collected during the germination trials. For the full data set refer to the CD-ROM.

Table 8.1 Number of viable oat seeds showing signs of germination per week (W). Ten oat seeds were plated per dish. These were kept in a germination cabinet for three weeks and under laboratory for a further seven weeks.

Dish No.	W 1	W 2	W 3	W 10
1	7	9	10	10
2	8	9	9	9
3	10	10	10	10
4	8	9	10	10
5	9	10	10	10
6	8	10	10	10
7	10	10	10	10
8	9	10	10	10
9	10	10	10	10
10	10	10	10	10

Appendix B

Potting trial raw data

This Appendix gives an example of the data collected during the potting trials. For the full data set refer to the CD-ROM.

Germination data

Table 8.4 Number of viable oat seeds showing signs of germination/growth per week (W). Ten oat seeds were planted per punnet. These were kept in a tunnel house for ten weeks.

Punnet No.	W 1	W 2	W 3	W 4	W 5	W 6	W 7	W 8	W 9	W 10
1	0	10	10	10	10	10	10	10	10	10
2	0	10	10	10	10	10	10	10	10	10
3	0	10	10	10	10	10	10	10	10	10
4	0	9	10	10	10	10	10	10	10	10
5	0	9	9	9	9	9	9	9	9	9
6	0	10	10	10	10	10	10	10	10	10
7	0	10	10	10	10	10	10	10	10	10
8	0	10	10	10	10	10	10	10	10	10
9	0	9	10	10	10	10	10	10	10	10
10	0	9	10	10	10	10	10	10	10	10

Growth data

Table 8.7 Hight (mm) of viable oat seeds from punnet no 9 per week (W). For the full data set refer to CD-ROM. Ten oat seeds were planted per punnet. These were kept in a tunnel house for ten weeks.

W 3	W 4	W 5	W 6	W 7	W 8	W 9	W 10
47	175	172	205	219	220	219	215
138	96	110	109	129	137	136	135
109	129	129	127	111	115	117	117
135	169	170	134	186	202	202	201
84	109	114	121	188	147	148	149
132	159	165	202	137	146	146	145
136	184	189	185	222	224	225	219
121	154	163	159	207	207	207	203
115	140	140	136	180	181	181	178
128	166	169	174	210	208	209	209

Appendix C

Photos of animals observed at the bait stations

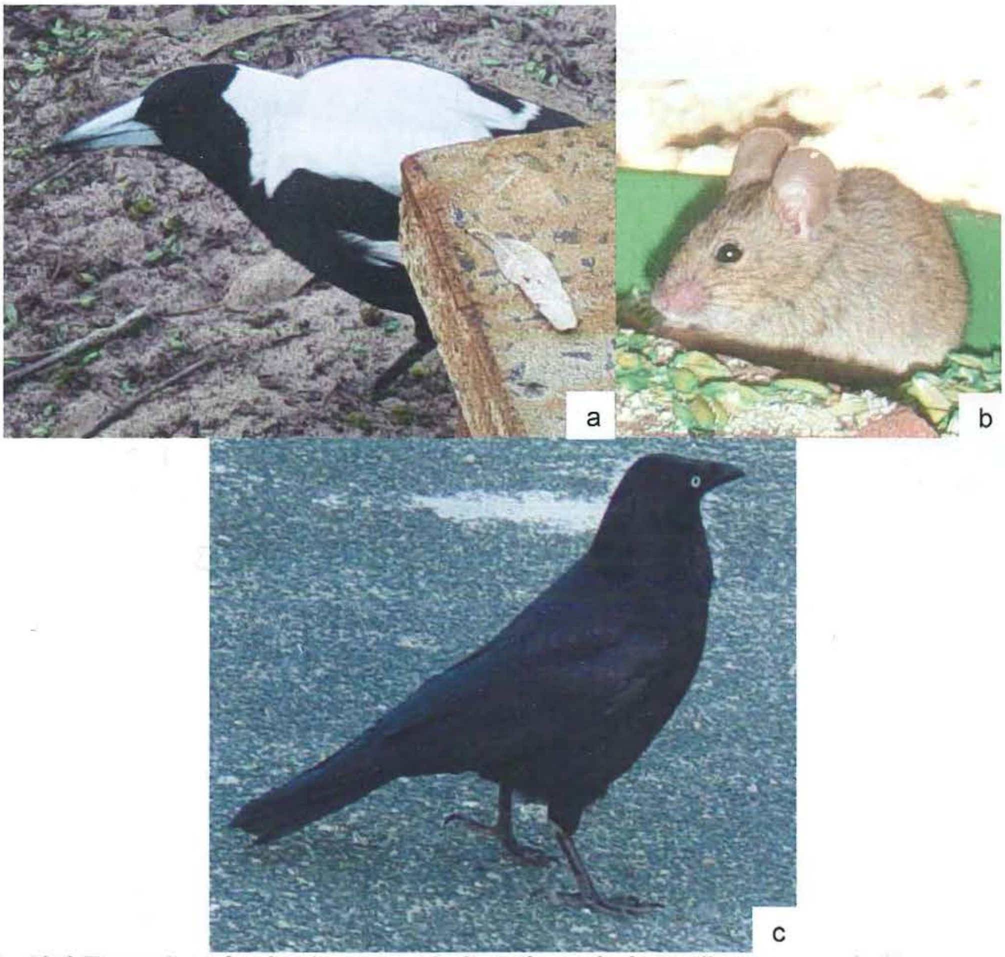

Plate 10.1 Examples of animals seen at bait stations. A: Australian magpie; b: House mouse; c: Australian raven (Photos: Malin Kordes, 2004).

Appendix D

Scats that aided with the identification of animals visiting the bait stations.

Plate 11.1 Fresh rabbit pellets. Tape measure for scale (Photo: Malin Kordes, 2004).

Plate 11.2 Rat scats found at the bait stations, demonstrating the variability of form and colour. Rodent scats can greatly vary in size and appearance depending on the type and amount of food. Tape measure for scale (Photos: Malin Kordes, 2004).

Appendix E

Diggings that aided with the identification of animals visiting the bait stations.

Plate12.1 A rabbit digging in loose sand. Often two rabbit pellets are deposited on the sand mount; here it is only some urine. Tape measure for scale (Photo: Malin Kordes, 2004).

Plate 12.2 A Painted button-quail scratching. Tape measure for scale (Photo: Malin Kordes, 2004).

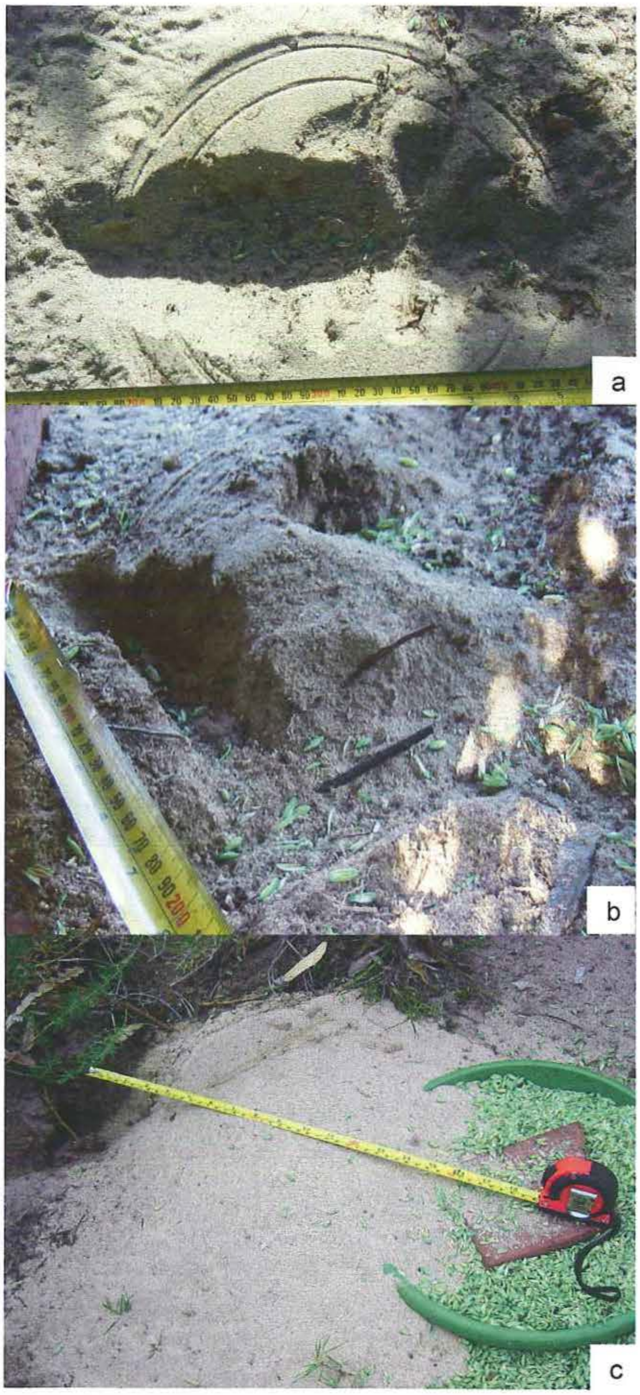

Plate 12.3 Examples of rodent diggings: a) digging under a saucer in soft sand; b) digging under a saucer in hard soil; c) digging at the side of a drum. Tape measure for scale (Photos: Malin Kordes, 2004).

Appendix F

Feeding signs that aided with the identification of animals visiting the bait stations.

Plate 13.1 Dispersal of oat seeds by birds (Photos: Malin Kordes, 2004).

Plate 13.2 Feeding signs of rodents. A: husks and pieces of the kernel; b: husks in a little pile. Tape measure for scale (Photos: Malin Kordes, 2004).

Appendix G

A draft for an information brochure about the use of pindone in Bold Park ***(see next page)***

Why baiting in Bold Park?

Bold Park is currently undergoing one of the largest restoration and research programs in Australia. Restoration is mainly undertaken by planting greenstock in the form of seedlings and juvenile plants.

PICTURE OF PLANTING

It has been noted though that feral rabbits are extensively grazing the new seedlings and juvenile plants. As the recruitment of new plants is vital for the survival of the bushland the grazing by rabbits is not only threatening the restoration effort but also the survival of the bushland itself.

PICTURE OF GRAZED PLANT

The evaluation of current rabbit control methods showed that baiting with pindone is the most appropriate method to control rabbits in Bold Park. Before the initiation of such a baiting program the general public will be informed about the program.

Who to contact to find out more information

Bold Park

Contact the

Bushland Manager of Bold Park

on

93870800

LOGOS OF ECU AND BGPA

LOGO OF BOLD PARK

Pests in Bold Park

The European Rabbit

(*Oryctolagus cuniculus*)

Where did the rabbit come from?

The European Rabbit has its origins in Spain but is now found in most temperate regions of the world. The rabbit was successfully introduced to Australia in 1859 near Geelong, VIC. The population grew quickly and by the 1920's the rabbits colonised most of the southern half of Australia.

Why are rabbits a pest?

Agricultural damage

Rabbits have a great impact on the productivity of farms and market gardens through extensive grazing on pastures. The annual loss is estimated at around $600 million per year.

PICTURE OF DAMAGE

Environmental damage

•Through the grazing of plant seedlings the regeneration of native plants may be prevented. This can lead to extreme changes in the structure of bushlands.

•Rabbits cause local disturbance through their burrows and dung mounds. This can lead to soil erosion, greater weed invasion, and the destruction of habitat essential for native animals.

•Rabbits reduce the amount of food available to native animals.

•Rabbits provide a good food source for other pests such as foxes and cats, which in turn can have a negative impact on native species.

Current rabbit control methods

Currently, a number of different methods are used to control rabbit populations. These include:

•Warren fumigation

•Warren ripping and harbourage destruction

•Rabbit proof fencing

•Biological control through Myxomatosis and the rabbit calicivirus

•Poison baiting with 1080 or pindone

Baiting is conducted using oat seeds impregnated with either 'one-shot 1080' (sodium monofluoroacetate) or 'pindone' (2-Pivalyl-1,3-indandione). In an urban bushland reserve pindone is more preferable because of its low poisoning hazard to cats and dogs as well as the availability of a reliable antidote, Vitamin K. Poisoning is carried out by either laying trails of poisoned oats or by presenting poison oats in bait stations. The latter method is preferred as the oats are less accessible by non-target species.