Controlling pests in New Zealand sanctuaries: Varying the spatial distribution of the standard grid system in a mainland conservation project.

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Abstract

A toxin reduction study was carried out in the Waitakere Ranges, west of Auckland City, New Zealand. The Auckland Council (previously called the Auckland Regional Council) manage more than 20, 000 hectares (ha) of native ecosystems within the Waitakere ranges using varying pest control methods and regimes. The 'Ark in the Park' (AiP) is part of this 20,000 ha protected habitat and it is intensely managed as a conservation reserve. AiP employs volunteers, Auckland Council staff, researchers, contractors and a full time project manager to monitor both pest and native species densities, deploy baits and traps, and inform the public of the importance of active pest management. The use of toxins to control pests can be controversial and decreasing poison usage and thereby reducing potential by catch of non-target species is an important and under studied aspect of conservation biology. In this study I tested the ability of pest control to meet targeted rodent densities when the density of bait stations was significantly reduced.

The study area was a 333 ha block of native forest adjoining the existing AiP conservation reserve, which at the time of the study represented 1200 ha of the Waitakere Ranges under pest control. The aim of the study was to replicate the standard AiP pest control methodology but reduce the density of poison bait stations. I then compared the density of rodents achieved within this reduced toxin study area with two control sites, one without rodent control and one with the standard rodent control methods used within AiP.

The existing AiP rat control methodology employs a 100 X 50 metre (m) grid of **Philproof®** bait stations, baited with pre-bagged Brodifacoum bait. In conjunction with this, mustelid (*Mustela spp*) and feral cat (*Felis catus*) control is carried out utilising existing track networks managed by the Auckland Council. In the current study this pest control programme was altered by increasing the distance between stations from 50m to 100m giving a control grid of 100 X 100m. Along the perimeter of this research grid, a

150m wide buffer was installed where bait stations are placed in a 100 X 50m pattern to reduce reinvasion of rats from non-pest controlled areas adjacent.

This study showed that at 100 X 100 m spacing overall rat density could be, as measured by baited tracking cards, controlled to 3%, with 10% density at the perimeter and 0% in the core of the area. As a direct result of this project additional areas under pest control have now been added to AiP with a current total pest controlled area of 2500 ha. In conclusion, this study has resulted in an additional 1200 ha of successfully pest controlled area in the Waitakere Ranges using significantly less toxin for the initial knockdown, lower costs, and less equipment and effort. It is recommended that future investigations examine whether the required rodent control is able to be sustained over much longer periods of time using the study technique trialled here.

Preface

Thesis outline.

The overall aim of this thesis was to examine whether an alternative baiting technique could be applied to an area that had not previously received pest control. An area adjacent to an existing pest control project was chosen, so that direct comparisons could be made, and the methods used for this existing area replicated, with only one variable changing. That variable forms the basis of the study for this thesis and enables me to ask the question: "Can we use a lower density of poison bait stations, and still achieve the low rodent densities necessary to meet conservation targets?" In brief, this is achieved by changing the standard pest control grid pattern of 100 X 50 m spacing, to 100 X 100 m spacing while keeping all other pest control processes the same. Rodent densities were then measured over time within the study area using baited tracking cards and compared with densities of rodents in areas with 100 X 50 m bait stations.

Thesis structure.

The thesis includes four chapters. The first chapter is a review of current literature on pest control in New Zealand and provides the background and justification for this study. The second chapter gives an overview of the existing pest control project, known as the 'Ark in the Park'. This project's pest control methodology is briefly described. The third chapter describes the experimental study with detailed methodology of how toxins were reduced. Chapter three also includes the main results from this research. In the final chapter I discuss the suitability of using reduced toxins to achieve rodent densities that not only provide native fauna with the opportunity to grow and maintain viable populations but also significantly reduce the costs of pest control. I make recommendations based on those findings and suggest areas of future research on this topic.

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Chapter 1 General Introduction

The impacts of ship rat (Rattus rattus) *and Norway rat* (R. norvegicus) *on New Zealand Wildlife.*

Since their first arrival in New Zealand with humans c. 700bp (Wilmshurst, et al., 2008), rodents have had a large effect on New Zealand's biodiversity (Atkinson & Cameron, 1993; Atkinson, 1996; Fukami, et al., 2006). Kiore *(R. exulans)* (McCallum, 1986) were the first rodent species to arrive in New Zealand and came with East- Polynesians in the 13th century. After 1840, the Norway rat (*R. norvegicus)* and the ship rat *(R. rattus)* arrived with European settlers. The result was significant retractions of many biota and numerous species extinctions (Towns & Daugherty, 1994; Burney & Flannery, 2005). While in many cases the full impact of rodents is unknown, they have had notable and documented effects on numerous New Zealand species including birds (Moors, 1983), reptiles (McCallum, 1986; Towns & Daugherty, 1994) and invertebrates (Parmenter & Macmahon, 1988). Furthermore, rats are also known to eat large quantities of seed (Beverage, 1964), thus possibly competing with native species for food and reducing forest regeneration potential (Innes, et al., 1995).

The effect of rodents on arrival in a habitat previously rodent free can be both devastating and immediate. This is highlighted by the documented invasion by Norway rats to Big South Cape Islands in the early 1960's. Within five years of the rats arriving, six birds species were exterminated (Bell, 1978). *"Habitat alterations and occasional human predation may have contributed to a range of contractions, but the primary factor in extinctions is almost certainly introduced mammals, especially rats"* (Towns & Daugherty, 1994).

Other pest introductions to New Zealand, that are present in the research area.

Since their planned introduction to New Zealand in the 1880's as a bio-control for rabbits (Thomson, 1922), the stoat (*Mustela erminea*) has caused further reduction in native biodiversity (Atkinson, 1996; Wilson, et al., 1998). Other members of the introduced mustelid family were intentionally established: the ferret *(Mustela furo)* for the fur trade, and weasels *(Mustela erminea)* for control of mice *(Mus musculus)* and rats. All three mustelid species have had devastating effects on the diversity and density of native fauna (Towns & Daugherty, 1994; Macphee, 1999).

The Waitakere Ranges, located West of Auckland, are now home to numerous other invasive pest species including feral pigs *(Sus scrofa)*, feral cats *(Felis catus)*, brush tail possum *(Trichosurus vulepcula)*, and feral goats *(Capra hircus)*. All of these species survive well in the area and are considered established.

1.1 General ecology of rodents.

Worldwide distribution.

Retractions in biota resulting from the introduction of Norway and ship rats have been observed around the world in areas as diverse as the Caribbean, the Aegean, Seychelles, Mascarenes, New Zealand, the Galapagos and elsewhere in the South Pacific (Case & Bolger, 1991). *R. norvegicus* is thought to have originated in north-eastern China and spread westward (Johnson, 1962), first reaching European cities around the early eighteenth century (Barrett-Hamilton, et al., 1921). They moved across the continent west from China arriving in European cities by land, whereas *R. rattus* were accidental introductions arriving aboard ships plying their trade between India and Europe well before the Norway rat (Yosida, et al., 1974; Atkinson, 1985). *R. norvegicus* is now established in Eurasia, China, Korea, Japan, North and coastal South America and locally in Africa, southern Australia and New Zealand (Innes, 1990). *R. rattus* originated from south-western Asia, primarily India and Pakistan (Yosida, et al., 1974). They are now distributed across the planet, excluding the polar regions (Atkinson, 1996). The total population of ship rats is made up of five chromosomal races of uncertain taxonomy (Baverstock, et al., 1983). They may indeed be different species, as they are not known to hybridise (Watts & Aslin, 1981; Innes, 1990).

Spatial distribution.

R. norvegicus have home ranges that are similar in size to *R. rattus*, with the longest recorded distances travelled being 850m for a female and 954m for a male found by one study based in Wales (Hartley & Bishop, 1979). However, this study also found the median distances travelled by female and male rats in a single night were only 4m and 52m, respectively. The median distance travelled during a seven night sampling period was about 24m for both sexes. Overall, no significant differences between the distances travelled by the sexes or by different age groups and little seasonal variation has been found (Hartley & Bishop, 1979; Macdonald, et al., 1999).

R. norvegicus is an excellent swimmer, regularly covering stretches of water up to 1km across (Russell, et al., 2008b), and studies have shown that they will even go diving for food sources such as molluscs (Galef Jr, 1980). *R. rattus* although not as strong a swimmer, will still readily swim 100m, and has been recorded swimming 500m (Duncan, et al., 2008).

The area over which ship rats move, or home ranges is found to be variable, with adult male r. rattus typically occupying up to 1.1ha, and adult females about one third of that at 0.3ha (Hooker & Innes, 1995). The distance moved by the female is typically up to 100m, but can be greater, with the male moving up to 700m as shown by radio tracked individuals in Rotoehu forest (Hooker & Innes, 1995; Blackwell, et al., 2002; Russell, et al., 2009) which correlates with home ranges observed in other parts of the world (Goodyear, 1992; Tobin, et al., 1996).

Based on records of trapped individuals, ship rats are by far the most populous of the rat species found in the Waitakere Ranges (Colgan, 2010). Of 861 rats caught in kill traps, only one has been positively identified as *R. norvegicus* (Colgan, 2010). This may be due to *R. rattus* being arboreal (McCartney, 1970; Harper, et al., 2005), and *R. norvegicus* being commensal with humans and preferring areas around water and streams (Innes, et al., 2001; Harper, et al., 2005; Traweger, et al., 2006).

Social organisation and behaviour.

The social structure of *R. norvegicus* groups is strongly hierarchical, where dominance of males is determined primarily by age (Macdonald, et al., 1999). Younger males can be excluded from good breeding and feeding areas and forced to occupy areas where no viable females are present (Gärtner, et al., 1981; Adams & Boice, 1989; Macdonald, et al., 1999). The social status in colonies becomes fixed, and does not change even when subordinate males become bigger than their superiors (Calhoun & Service, 1963).

Both the Norway rat and ship rat are mainly nocturnal, with the highest rate of activity for *R. norvegicus* occurring just after sunset, and just before sunrise (Innes, 1977; Macdonald, et al., 1999), while *R. rattus* is active all night, and this seems to be consistent worldwide (Henning & Gisel, 1980; Tobin, et al., 1996). Rats are neophobic (Innes, 1990), but offsetting this is an inquisitive nature, and memory of the old and the new objects in their environment (Ennaceur & Delacour, 1988; Bruchey, et al., 2010). Social processes between rats such as social transition have been observed where young rats are able to work out ways of accessing food where there elders cannot (Aisner & Terkel, 1992). Terms such as 'social learning' and 'culture' have been applied to both species, and is believed to contribute strongly to their worldwide success (Macdonald, et al., 1999; Pierre, 1999).

Breeding ecology, reproduction and development.

The female *R. norvegicus* reaches sexually maturity at between 36-50 days of age (Meaney & Stewart, 1981). The female *R. norvegicus* will be in oestrus for 1 night once every four days (Hardy, 1970; McClintock, 1984). She can be pursued by several males on this night, and while male hierarchy will determine access to food, this does not guarantee exclusivity with a female, and she may mate with multiple males while in oestrus (Macdonald, et al., 1999). The male ascertains the female's reproductive status by her body odour (Macdonald, et al., 1999; Innes, et al., 2001). Gestation lasts 21-24 days, resulting in 6-8 pups (Innes, et al., 2001).

Similarly, the *R.. rattus* oestrus cycle is four to six days, and the gestation period is around 20-22 days (Asdell, 1946; Rowett, 1965). The litter of three to ten pups reach sexual maturity in three to four months (Watts & Aslin, 1981). The average time between litters is 32 days, with pups being weaned at 21 to 28 days (Cowan, 1981).

Diet.

One of the reasons attributed to the success of humans, and both the Norway rat and ship rat species are their omnivorous and opportunistic approach to diet (Moors, 1985; Melcer & Alberts, 1989; Gerrish & Alberts, 1995; Carlton & Hodder, 2003). Rats will eat anything humans eat and more. Their diets include cereals, meat, fruit and vegetables, all cooked or raw. Rats occupying farms will eat stored grains and stock feed, crops, weeds and grass seed. Both ship and Norway rats will prey on small birds, depredating eggs, chicks and the incubating adults. (Innes, 1990). Both rat species are known to also enter the marine system, and prey on any accessible marine life (Carlton & Hodder, 2003). In New Zealand certain seed and berry species seem to be favourites, such as miro *(Prumnopitys taxifolia)*, nikau palm *(Rhopalostylis sapida)* and hinau *(Elaeocarpus* *dentatus)*, which to the trained eye, may give clues to the presense of *Rattus rattus* (Daniel, 1975; Innes, 1990; Miller & Miller, 1995a).

Ecology of the Norway rat, R. norvegicus.

Also known as Brown rat, common rat, Water rat, Sewer rat and Pouhawaiki (in Maori). It is the largest of the three rat species found in New Zealand, the female ranging from 150-240 grams (g), and the male ranging from 190-270 g approximately (Innes, 1990). It is distinguished by a stout body, thick tail and relatively small ears. Like all rodents, Norway rats have an excellent sense of smell, sight and hearing. Scent signals play a crucial role in the life of this rat, playing a large part in its social interaction and identification of others (Clapperton, 2006). The strong sense of smell is for foraging and social interactions (Innes, 1990). They are also good climbers when necessary, but generally prefer to occupy the lower spaces of areas in which they are found. While the Ship rat will tend to occupy the tree tops, or upper reaches of buildings, the Norway rat will be found on the forest floor, and basements respectively. Norway rats are good swimmers, hence the name 'Water rat', and are known to swim distances of up to 2 km to reach islands off New Zealand's coast (Russell, et al., 2008a). Adult males have a very visible scrotum at the base of the tail, and all females have a hairless patch behind the urethral papilla. Nipples are visible on adult females only. (Innes, 1990; Russell, et al., 2005). Dietary studies of Norway rats in New Zealand have shown a wide range of food preferences including seeds, fruits, leaves, fern rhizomes, insects, molluscs, crustaceans and annelids (Beverage & Daniel, 1964; Moors, 1985) with some seasonal variation. Lepidopteran larvae, beetles and other invertebrates, plus eggs, birds and lizards are important for occasional protein, and island Norway rats will forage on the shoreline or go diving for food (Innes, 1990). On Breaksea Island, stomachs taken from rats trapped in 1984 contained invertebrates, shellfish, vegetation, feathers, fur, and flesh of birds and other rats (Taylor & Thomas, 1993).

An important ecological trait for this study that is demonstrated by Norway rats is adaptive sociality; they can live as almost solitary individuals or in colonies (Innes, 1990).

Plate 1.1 ***Rattus norvegicus,*** **Norway rat. Both male (Photos Andy Warneford and Idan Shapira).**

Ecology of the ship rat, Rattus rattus.

A medium sized rodent around 20cm long, with a scaly tail longer than the body (measured head to anus inclusive). However, size approximations should be treated cautiously as variations in size and sexual maturity will vary from year to year depending on conditions (Innes, 1990). The ears are large and thin, and can cover the rat's dark protruding eyes when stretched forward over them. They are a well groomed animal, with smooth fur and a distinctive smell (Innes, 1990). Ship rats are excellent climbers, can scale rough and smooth surfaces and easily access the smaller lighter branches at all canopy levels where many small bird species roost, and nest (Ewer, 1971). Radio-tracked ship rats have been found to be mostly arboreal (73% of locations above 2m), but were also frequently recorded on the ground, covering most of their home range every night, active continually between dawn and dusk, rustling through vegetation or vocalising (Dowding & Murphy, 1994). These factors make ship rats common prey of feral cats and stoats (Innes, 1990). Commensal ship rats often live in ceilings (hence their alternative name 'roof rat'), but unlike Norway rats, they rarely burrow although will do in un-forested areas, are unwilling swimmers, but have been known to swim to offshore islands, such as those 750m west of Great Barrier island (Innes, 1990). The skull and teeth are specially adapted to gnawing and grinding (Corbet, 1978; Innes, 1990). The large incisors grow throughout the lifetime of the individual and are self sharpening. The grinding molars also grow continuously, and the wear on these can provide a useful index for ageing and accessing the maturity of the individual (Corbet, 1978; Innes, 1990). Ship rats are amongst the most common mammals on the New Zealand mainland, but their presence is seldom observed due to their nocturnal, arboreal and shy habits (Innes, 1990).

Plate 1.2 ***Rattus rattus*, ship rat. Top two photographs are male, bottom two photographs are female (photos A Warneford).**

1.2 History of rodent control and monitoring in New Zealand.

History of techniques and pest-control grid systems from its beginnings on off shore islands.

It was known for decades that eradication of rodents from islands would benefit a wide range of biota, but achieving this was considered practically impossible and the focus remained on controlling rats rather than removing them (Thomas & Taylor, 2002; Towns & Broome, 2003). Correlating with human exploration and colonisation of the planet over many centuries, rats have spread and caused major conservation problems worldwide (Atkinson, 1985). New Zealand is no exception, with the extirpation of many species in this country being attributed to rats (Towns & Daugherty, 1994; Atkinson, 1996; Burney & Flannery, 2005).

However, after the modest beginnings of rat removal from islands, including the accidental eradication on Maria island (1 ha) in the inner Hauraki Gulf (Merton, 1978; Thomas & Taylor, 2002; Towns & Broome, 2003) through to the eradication of rats from Campbell Island (11300 ha) 700km south of Stewart Island and the warm temperate Raoul Island (2938 ha) (Towns & Broome, 2003), it has been proven that rodent eradicated from offshore islands is possible and has widespread benefits for the local ecology (Clout, et al., 1995; Empson & Miskelly, 1999; Towns & Broome, 2003). Furthermore, the research and work carried out on New Zealand islands, has led to ambitious eradications of rats being undertaken on islands overseas such as Queen Charlotte Islands, Canada 1995 (Thomas & Taylor, 2002).

During the evolution of techniques for the eradication of rats from islands over ever increasing sized sites, various grid systems ranging in spacing from 10 X 5 m spacing to 100 X 100m spacing was tried, and eventually a grid system of 100 X 50 m was found to work reliably (Thomas & Taylor, 2002). Topography, vegetation, and proximity to coastal areas were all considered, and sometimes it was found that direct 'hand broadcast distribution' of bait in difficult to access areas, and offshore stacks produced best results

(Thomas & Taylor, 2002). A 200 X 200 m grid system has been trialled in Marpara, following tracks and ridges (Thompson, 2011), but did not achieve the rat densities required to be considered affective for management to minimise detrimental effects to biodiversity (Parkes & Murphy, 2003). After consultation with experts, the current 100 m X 50m grid system was adopted by the Ark in the Park project (the variation of which to 100 X 100 m studied for this research project) as the basis for its rodent control programme (Sumich, 2006).

Moving the fight from offshore islands to the mainland.

While important advances have been made in pest control on offshore islands, much of New Zealand's biota remains on the mainland, where restoration of ecosystems and species specific conservation has much to add to preserving biodiversity in this part of the world (Saunders & Norton, 2001). Mainland sites were first treated to eradicate rats using 1080 *(sodium monofluroacetate)* and Brodifacoum in 1995 (Innes, et al., 1995) for the purposes of ecological restoration. Following the successful eradication of rats from five islands, the biggest at that time being Somes Island (32ha). DOC established six mainland island projects through 1995 and 1996; four in the North island, and two in the South island (Saunders & Norton, 2001). These mainland islands ranged in size from the 117 ha Paengara Reserve to the 6000 ha Hurunui project. All of these projects were 'ecosystem recovery based', with emphasis placed on controlling introduced herbivores and carnivorous predators (Innes, et al., 1995; Saunders & Norton, 2001).

Most importantly, the success of offshore islands showed the impact of mammalian pests on native biota. It also showed that recovery of ecosystems over large areas could be achieved, and it was with this intent that intensive pest control was applied to mainland sites, where it was hoped species specific protection could also be achieved. The *Convention on Biological Diversity* (Convention on Biological Diversity, 1993) which the New Zealand government is a signatory to, underpins the importance of 'in-situ' protection and conservation of ecosystems, therefore providing habitat to the native and endemic species that habituate those areas (Anon, 1993a).

Intensive, on-going management regimes are expensive. By 1998, the six mainland sites initiated by DOC had an annual budget of $NZ1.8 million (Saunders & Norton, 2001). Over time, both the ecological and financial benefit of such mainland projects will need to be assessed. It was hoped that these original six mainland sites, would in turn motivate other organisations and conservation groups to initiate additional projects, so the burden of cost could be shared, and the ecological benefits spread further, in turn, providing community benefits (Innes, et al., 1995; Saunders & Norton, 2001; Bell, 2003). Mainland conservation projects are generally at sites that are easier to access than offshore restoration sites and the involvement of volunteers in such projects provide numerous benefits to the community including;

- Assist in implementing DOC conservation work.
- Improve support for DOC.
- Improve community awareness of conservation issues.
- Empower community groups to achieve their conservation goals (Bell, 2003).

As these mainland projects develop, and objectives of managers are refined, the opportunity for research arises, and indeed becomes necessary (Saunders & Norton, 2001). Project staff, and committed volunteers often work alongside each other, gathering data, implementing research findings and formulating further research that is required (Saunders & Norton, 2001).

History of trapping to control rat populations.

Techniques for trapping rats have been developed (Innes, 2011), and may be an option to projects or groups where toxin use is for some reason not permitted. Spacing of traps is typically 100 X 50 m, checked daily until numbers are reduced, then once every two to three weeks (Innes, 2011). Victor© professional snapback and DoC 150 & 200 traps are all approved by the National Animal Welfare Advisory Committee (NAWAC) for use. However, this method of control for rats is more labour intensive and/or more costly (Innes, 2011) than poisoning.

Where absolute abundance needs to be established though, and/or for the calibration of relative rat densities, the method of 'trapping rats to zero' is an essential part of the process (Brown, et al., 1996; Blackwell, et al., 2002; Innes, 2011).

Control of rodents over large areas can be achieved using trapping, but the workload, equipment needed and the resources used are far greater than for methods using toxins (Wilson, 2011). Puketi Trust, Northland New Zealand controls 5500ha with a core area of 670ha of contiguous forest using trapping, and achieves relative rat densities as required to achieve minimal damage to the ecosystem. However, the managed area requires monthly servicing year round to achieve this, with fortnightly servicing during bird breeding season to achieve wildlife management goals. When using toxins, baiting is typically carried out two to three times per year at projects such as AiP, which are of a similar size (personal observation). Traps also have by-catch of non target species (Warburton & Orchard, 1996).

Rat monitoring techniques used at the Ark in the Park Project.

Controlling and/or eradicating rats is known to have benefits for a wide range of biota (Innes & Barker, 1999) but as with any undertaking, the efficacy of the techniques and effort being applied needs to be assessed and recorded. This information is essential for managers, and is also a powerful motivational tool for conservation organisations, particularly where large proportions of the labour force are volunteer based (personal observation).

Conservation managers now commonly use tracking tunnels to establish relative density and activity of rat populations in their sanctuaries (Gillies & Williams, 2005). This system is standardised nationally, and a DOC protocol is available on the technique used for obtaining the necessary data, and analysis of that data (Gillies & Williams, 2005). The use of tracking tunnels for monitoring small mammals in New Zealand was first documented during the 1970's (King & Edgar, 1977). The system has many advantages but most importantly, tracking tunnels are more likely to give indication of the presence of rodents at low densities than traps (Gillies & Williams, 2005). Other important factors include a hard copy being produced by prints, which can be kept for archiving and longitudinal studies, and that larger areas can be surveyed with less work load over a shorter period of time than trapping (King & Edgar, 1977; Gillies & Williams, 2005).

Brodifacoum as a mammalian control agent in New Zealand.

Control of rodents and other pest species is a fundamental prerequisite in the rehabilitation of both island and mainland biodiversity conservation areas in New Zealand (Atkinson, 1990; Empson & Miskelly, 1999; Howald, et al., 2007; Harris, 2009; Howald, et al., 2010). Restoration of ecosystems to pre-human conditions will not be possible owing to the extinction of key biotic elements, however significant conservation progress can be made with pest control. The common method for rodent control in New Zealand is poisoning, with the two most common toxins used being 1080 *(sodium monofluoroacetate)* and the second generation anticoagulant, Brodifacoum (*Bromobiphenyl-tetrahydro-naphthyl-hydroxycoumarin*) (Gillies & Pierce, 1999). Poisoning is preferred to the alternative trapping method due to the labour costs associated with trapping (Beverage, 1964; Miller & Miller, 1995b; Nelson, et al., 2002).

Many successful island eradications have been achieved with the use of toxins (Towns & Broome, 2003), such as that on Campbell Island mentioned earlier(Towns & Broome, 2003). 1080 *sodium monofluoroacetate* is a commonly used agent (Miller & Miller, 1995b; Parkes & Murphy, 2003), particularly by the Department of Conservation (DoC). Brodifacoum is also a commonly used toxin, particularly under the brand names of Tallon®, and Pestoff® (Hoare & Hare, 2006). As rodents are rarely the only species forming part of pest control programmes in New Zealand parks, toxins are also useful for the eradication of feral cats *(Felis catus)*, rabbits *(Oryctolagus cuniculus),*hedgehogs *(Erinaceus europaeus)*, feral red deer *(Cervus elaphus),* feral pigs *(Sus scrofa)*, and feral goats *(Capra hircus).*

Rodent control programmes utilising toxins offer significant benefits to New Zealand's ecology and native biota. (Clout, et al., 1995). However, concerns have been raised as to the consequences for other species sharing the ecosystem with the target species, when toxins are used (Innes & Barker, 1999; Powlesland, et al., 1999; Hoare & Hare, 2006). The dilemma for managers though is in balancing the benefits and costs. Studies have shown, that based on present technology, knowledge and financial cost, that the ecological benefits out weigh the costs and damage caused by introduced pest mammals if they are not used (Innes & Barker, 1999). Over 90 islands around New Zealand have now been eradicated of introduced mammals enabling the implementation of restoration projects providing refugia for many native and endemic biota that show a positive response to predator control (Towns & Broome, 2003).

Mainland species recovery operations too benefit from the use of toxins to control introduced pest mammals (Powlesland, et al., 1999). The use of toxins in the preservation of some New Zealand biota such as the kokako *(Callaeas cinerea wilsoni)* is critical (Innes, et al., 1999). Notably some common species have also benefited from the use of this control toxin, such as Moreporks or Ruru *(Ninox novaeseelandiae)* (Fraser & Hauber, 2008), even where concerns of secondary poisoning have been raised (Eason, et al., 2002).

Also, some specific plant species such as northern rata *(Metrosideros robusta)* and kamahi *(Weinmannia racemosa)* seem particularly susceptible to damage from brush tail possums (Batcheler, 1983) and benefit from control of this introduced mammal using toxins (Payton, et al., 1997).

Brodifacoum: Technical data and information.

Bromobiphenyl-tetrahydro-naphthyl-hydroxycoumarin is a powerful second generation anticoagulant used for rodent pest control worldwide (Eason & Spurr, 1995b; Brown & Singleton, 1998). Brodifacoum and related substances such as Warfarin© act by binding to the enzyme vitamin K 2,3-epoxide reductase thereby causing haemorrhaging of blood vessels of internal organs resulting from the interference of synthesis by these vitamin K-dependent blood clotting factors (Thijssen, 1995; Eason & Wickstrom, 2001; Booth, et al., 2003). An essential cofactor for the synthesis of functional prothrombin and related blood-clotting factors is Vitamin K in its hydroquinone form (Thijssen, 1995). Brodifacoum accumulates in body tissues as it is not rapidly metabolised or excreted (Thijssen, 1995). This property makes it particularly effective as a control for rodents, as a lethal dose is normally consumed before the onset of any symptoms resulting from the bait. This largely avoids problems experienced with individuals becoming bait shy as has been recorded with 1080 and cyanide (Henderson & Frampton, 1999).

The LD_{50} for a white laboratory rat (oral) is 0.26 mg/kg B/W (body weight). The amount of Brodifacoum bait required to be eaten by an individual rat that will kill 50% (LD_{50}) of the individuals that do so, is 0.26mg/kg of body weight. The bait is supplied at a concentration of 0.02g/kg of active ingredient Brodifacoum. If the approximate weight of a Norway rat is 200g (Innes, 1990), then the amount of bait required to be eaten for a rat to receive a lethal dose is 2.6 g of bait. In its standard delivery form, this equates to around two bait pellets. See Plate 1.3.

Plate 1.3 Pestoff® bait in the standard delivery form of pellets. LD$_{50}$ = Two pellets.

Impacts of Brodifacoum on non-target species, and persistence in the environment.

From 2000, DoC has largely ceased the use of Brodificoum as a pest control poison due to this toxin's persistence in the environment (Innes & Barker, 1999). Although Brodifacoum is fairly insoluble in water, <10 mg/litre of water at pH 7, (Ogilvie, et al., 1997), concerns have been raised about the persistence of Brodifacoum in the environment (Eason, et al., 2002; Hoare & Hare, 2006; Eason, et al., 2008). Accumulation of anti-coagulants in non-target species including invertebrates (Booth, et al., 2003; Fisher, et al., 2007) and vertebrate species (Eason & Spurr, 1995b; Ogilvie, et al., 1997; Innes & Barker, 1999; Eason, et al., 2002; Hoare & Hare, 2006) has been identified in some individuals on various occasions. The lack of mammals naturally present in the New Zealand ecosystem means that key ecosystem roles are filled by birds, reptiles and invertebrates (Hoare & Hare, 2006). These non target species are not considered to be immediately at risk from the use of Brodifacoum (Empson & Miskelly, 1999; Innes & Barker, 1999). This means that products such as Brodifacoum are not only used for eradicating rodent pest species but is also often applied continuously to ecosystems for ongoing pest mammal control management and detection of mammalian reinvasions (Hoare & Hare, 2006). It has been suggested that the research on non-target effects of anticoagulant poison use in the wild is taxonomically unrepresentative, which is of concern to native (i.e. mammal-free) ecosystems particularly where poison is continually available (Hoare & Hare, 2006). The possibility of bio-accumulation or more correctly persistence and insects acting as 'carriers' of toxin exists in part because invertebrates do not have the same blood-clotting systems as vertebrates(Eason & Spurr, 1995b; Eason, et al., 2002; Fisher, et al., 2007).

The effects of Brodifacoum use have been studied in relation to 26 bird species, four fish species, seven aquatic invertebrate species and 11 terrestrial invertebrate orders and Brodifacoum bait consumption has been noted in two reptile species. However, there are no post-baiting monitoring data on amphibians, bats or parasites of these taxa. The effects on a localised population of shore skink, and individuals within that population have been studied (Wedding, et al., 2007). Theoretical effects of Brodifacoum on bats has been evaluated (Eason & Spurr, 1995b).

Certain species whose diet include small target species such as mice, rats 'and' non-target invertebrates are considered at elevated risk of secondary poisoning. This includes Moreporks, New Zealand Falcon *(Falco novaeseelandiae)* and the Australasian Harrier *(Circus approximans)* (Stephenson, et al., 1999). Because of invertebrates ability to consume anticoagulants and not be affected, lizards and reptiles are then also considered at high risk of secondary poisoning, due to their diet comprising largely of invertebrates (Wedding, et al., 2007).

1.3 Summary

Toxins including 1080 and Brodifacoum are extremely powerful and effective tools used to save many of New Zealand's native and endemic flora and fauna. While it is well recognised that their widespread and regular use requires ongoing research into their long term effects, little work has been conducted on how much poison is required to achieve pest control goals. To minimise these possible negative effects, an approach of continuous improvement and refinement in their use will improve the long term prospects for their use until alternatives and more specific solutions become available. Designing new large scale conservation initiatives as ‘experiments’ to test toxin deployment strategies is a relatively overlooked avenue for meeting the dual goals of increasing New Zealand’s protected areas and answering research questions about toxin use. Reducing the amount of toxin usage also reduces the cost and subsequently the amount of work required to maintain a managed area using these toxins. Reduction of toxin use has the additional advantage of cost effectiveness, which is of particular benefit to groups that are increasingly volunteer based. Refinement of the techniques employed in the use of Brodifacoum is considered necessary if the ongoing use of this highly effective toxin is to continue, especially in large scale operations (Taylor & Thomas, 1989; Eason & Spurr, 1995; Alterio & Moller, 2000). The research documented in the following thesis identifies one possible way of reducing the amount of toxin use in the environment and toxin bio-accumulation. Toxin usage reductions can be achieved in a number of ways; cycle the bait deployment less often, place less bait and any given spot or baitstation, or, as trialled in this study, reduce the amount of bait deployed by expanded spatial deployment.

Chapter 2 Ark in the Park existing pest control project.

2.1 Introduction

The Ark in the Park (AiP) community conservation project has been operating since 2004 as a partnership between the Royal Forest and Bird Protection Society (F&B) and the Auckland Council (AC, previously Auckland Regional Council). The project focuses on controlling pests within an unfenced 1200 hectare area in the Waitakere Ranges west of the Waitakere Dam and catchment. The intention with this project was to create a secure sanctuary and boundary area using poison bait stations and kill-traps. This is an alternative model to the sanctuaries that use predator-proof fences to protect 'mainland islands'. The advantage of using a "chemical barrier" is that it is a dynamic system whereby the boundary can be continually extended. Whereas, predator- proof fences do not allow sanctuaries to expand.

The project is located in the Waitakere Ranges 30 minutes drive 21.8 km west of Auckland city centre, near the west coast of New Zealand. Access to the site by road is relatively easy. The forest of the Waitakere ranges is good quality regenerating forest comprised primarily of broadleaf and podicarp species. The forest complexity and density is greater than both Little Barrier Island, and Kapiti Island sanctuaries of New Zealand (Staniland, 2007). Many of New Zealand's rare and endemic species live in this area including remnant populations of Long Tail bat (*Chalinolobus tuberculatus*) (Daniel & Williams, 1984), Pacific *(Hoplodactylus pacificus),* Auckland Green (*Naultinus elegans elegans)*, and Forest gecko (*Hoplodactylus granulates)*, and Hochstetter's Frog *(Leiopelma hochstetteri).* Many other more widespread and commonly found species are also present in the Ark in the Park sanctuary area.

Although accessible, the lack of public transport to the site makes it quite isolated. There is no accommodation available on site.

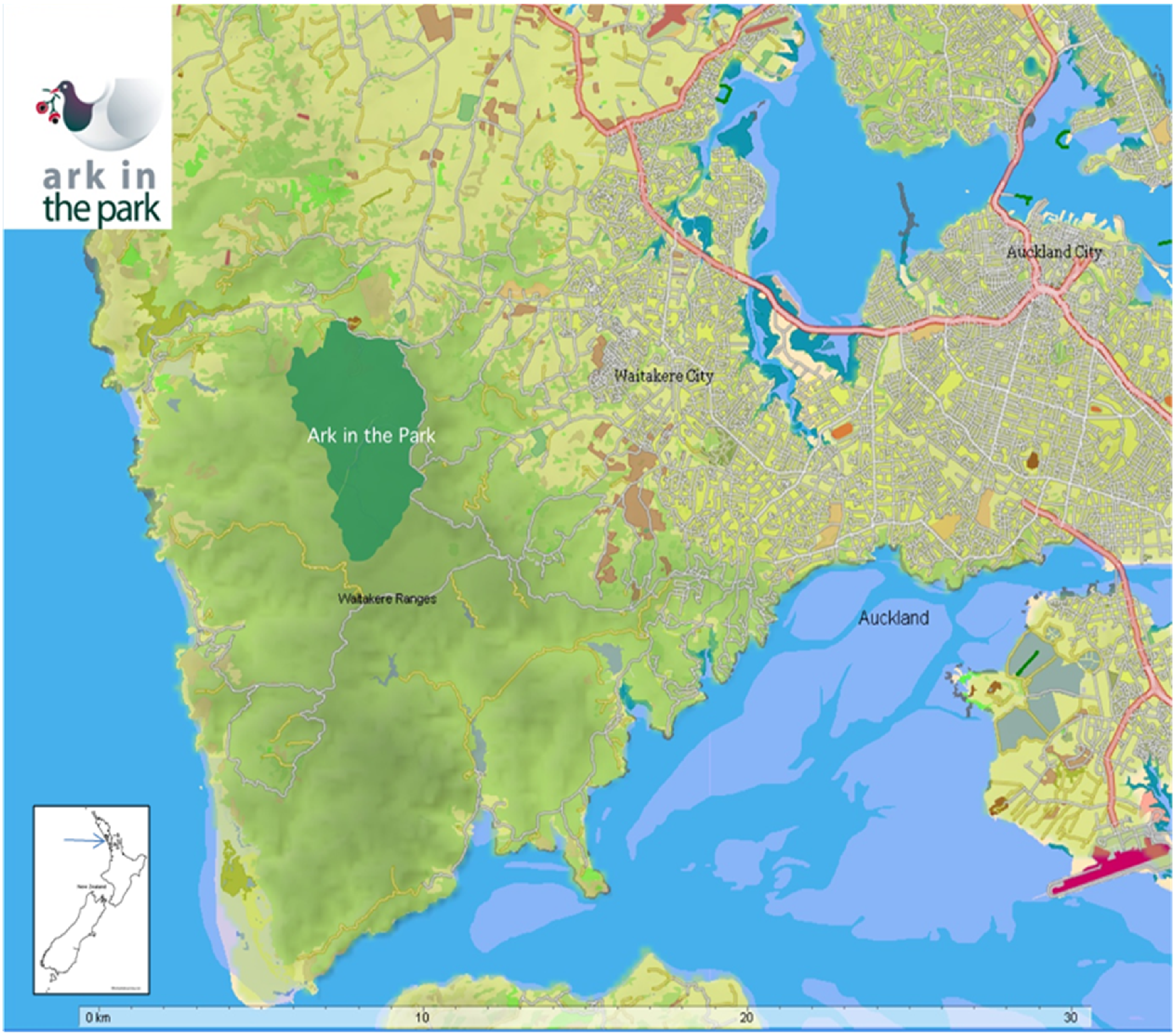

Figure 2.1 Location of the Ark in the Park project and proximity to Auckland City (Reproduced by permission of M Colgan, AiP).

The current pest control regime in this area is to poison bait for rodents, and kill trap for stoats, weasels, ferrets and feral cats using a grid formed by laying bait-lines 100 metres apart, with bait-stations 50 metres apart down each bait-line (described fully in chapter 3). The method used for the research block follows the method of the AiP project, with the only variation being that of the 'toxin optimisation' study question.

Goals of the Ark in the Park.

AiP aims to hold rodent levels at less than 10 percent presence (as indicated by tracking cards - a measure of relative density, see Fig 2.7). The primary purpose of pest control in the AiP area is to improve local ecology, and maintain biodiversity. Regular bird counts are carried out to assess avian population responses to pest control efforts. Invertebrate monitoring is ongoing, with all species found being catalogued by F&B. The project employs a set of 10 rat monitoring tunnels per 100 hectares of pest controlled area meeting industry standard protocols.

The slogan of this group, *"From the ridges to the sea; restoring the natural world of the Waitakeres"*, indicates their intention of a systematic approach to increasing the area pest controlled by the project. However, the size of the area controlled is limited by both the volunteer work force available and the funds available for equipment.

Limitations are somewhat mitigated by an "Arkipelago" (sic). (Sumich 2005) philosophy employed by the group. (Figure 2.2). The plan has been to 'link up' with the other conservation groups in the region to enable all projects to assist each other's growth and the connectivity of protected regional biodiversity.

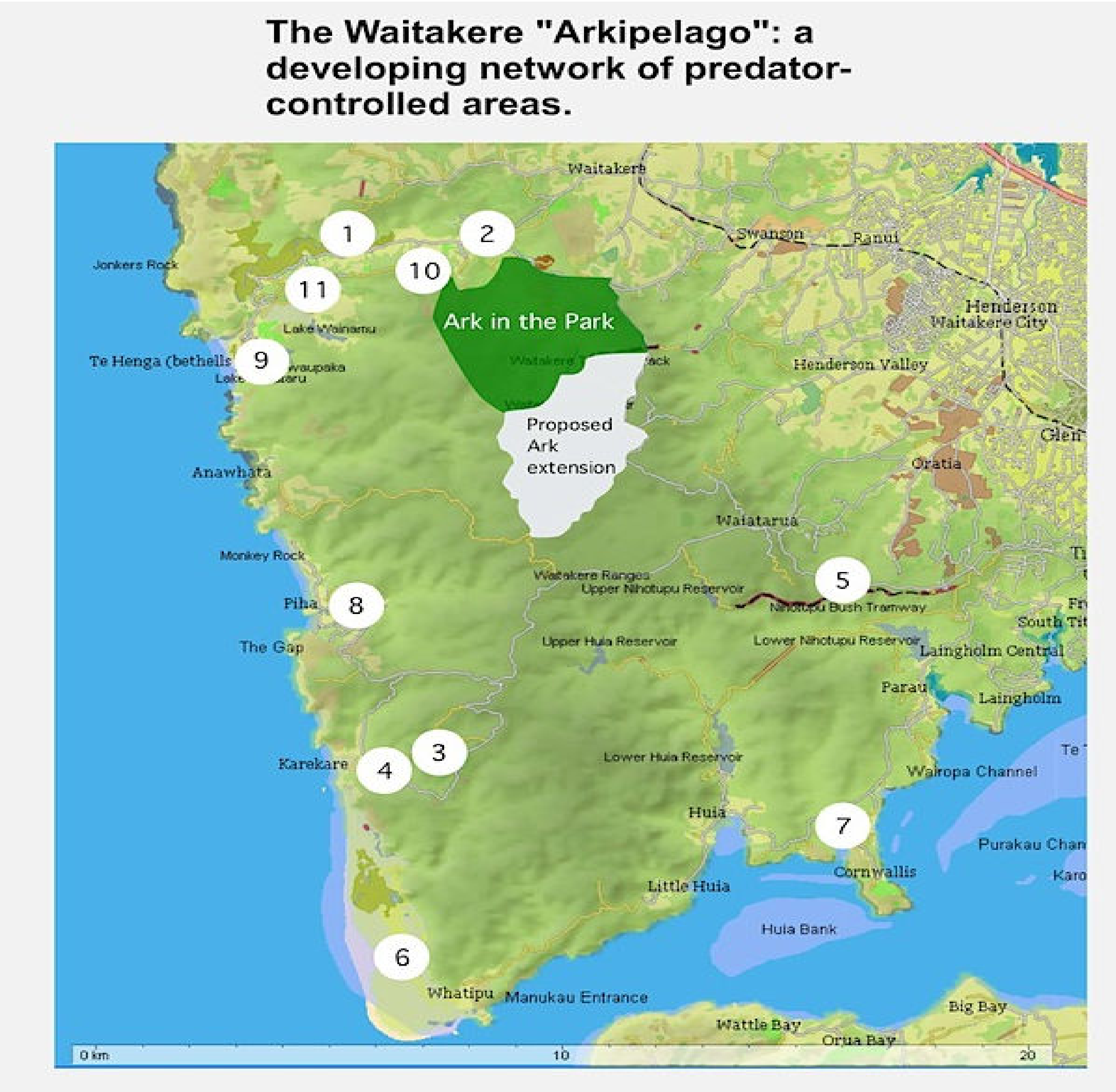

Figure 2.2 **Map showing the Archipelago concept, or 'Arkipelago' (Reproduced by permission of M Colgan, AiP). Numbers refer to; 1) Matuku reserve, 2) Forest Ridge Communitry group, 3) La Trobe restoration project, 4) Lone kauri restoration project, 5) Arataki community conservation group, 6) Whatipu community and AC partnership, 7) Huia Cornwallis landcare group, 8) AC pest control at Piha, 9) Costal dottrel protection, 10) Cultural flax weaving AC staff, 11) Riparian river care.**

Predominantly volunteer/community led, conservation projects that have been carried out across the Ranges of Fig 2.2. These include:

1. Forest and Bird's Matuku Reserve – approximately 120 ha of predator control (possums, rats, mustelids, goats), overseen by the Forest & Bird Ranger.
2. Forest Ridge community – approximately 120 ha, largely bush covered and part of the Ark in the Park Buffer Zone.
3. La Trobe Restoration Project – 200 ha at Karekare targeting rodents and possums using Brodifacoum. The project began in 2001 and is now focusing on monitoring the impact of rodents on arthropods. The project also collects information on Hochstetter's frog populations in the project area.
4. Lone Kauri Restoration Project – 350 ha at Karekare targeting rodents and possums with bait and trapping mustelids. Control began in 2001.
5. Arataki Visitors Centre predator control – Initiated in October 2001. 250 ha area of predator control around the Centre and associated visitor tracks, targeting rats, possums, mustelids, hedgehogs and rabbits. Volunteers carry out the control, overseen by ARC staff. There is also a partnership (initiated in March 2003) with Watercare, which manages 20 traps targeting mustelids along the tramline to the Upper Nihotupu Dam.
6. Whatipu – 600 ha focusing on shorebird protection targeting rodents, possums, mustelids, hedgehogs, and cats (not as intensive as the Ark in the Park project). Control began in September 2003 and is funded by Friends of Whatipu Inc. in partnership with the ARC.
7. Huia/Cornwallis Landcare Group – 12 ha targeting rodents, possums, mustelids and hedgehogs using traps. Control began in October 2006.

8. Auckland Council pest control at Piha – ARC rangers assist with the Lone Kauri Restoration Project and also have traps for mustelids on the headlands at Te Waha Point where seabirds are known to breed. Pindone is also used to control rabbits in the Piha dunes.
9. Coastal protection for NZ dotterel and other native sea/shorebirds at Bethells beach – targeting mustelids and rats in the dunes behind the beach (ARC Biosecurity and local community) and also protecting breeding birds around Bethells and O'Neills beaches.
10. Cultural flax planted for weaving etc – on ARC farmland alongside the Waitakere River (Pae o te Rangi farmland). Overseen by ARC staff.
11. Riparian Waitakere Rivercare – replanting of riparian areas along the Waitakere river from the Te Henga Rd bridge to the Te Henga wetland.

Another local project not included in Fig 2.2 is Twin Streams – 56 km covering the Huruhuru Creek and Henderson Creek catchments. Streams and tributaries include Swanson, Waimoko, Momutu, Henderson, Waikumete, Whakarina, Bishop, Opanuku, Oratia and Pixie. The aim is to restore streams, linking the Ranges to the sea and to engage the community. Weeding and planting are key, with some property purchases, covenants and community contracts etc. Started in 2002. No pest control is currently being undertaken.

2.2 Design of the Ark in the Park project.

The AiP 1200 ha area operates a 100 x 50 m grid of bait stations. Stoat trapping is carried out on the main tracks, at around 200m spacing, see Fig 2.4. The straight dashed lines indicated the intended position of baitlines. The small white squares indicate stoat traps. The yellow squares indicate Tims traps, used occasionally if the Belisle cat traps repeatedly produce by catch such as possums.

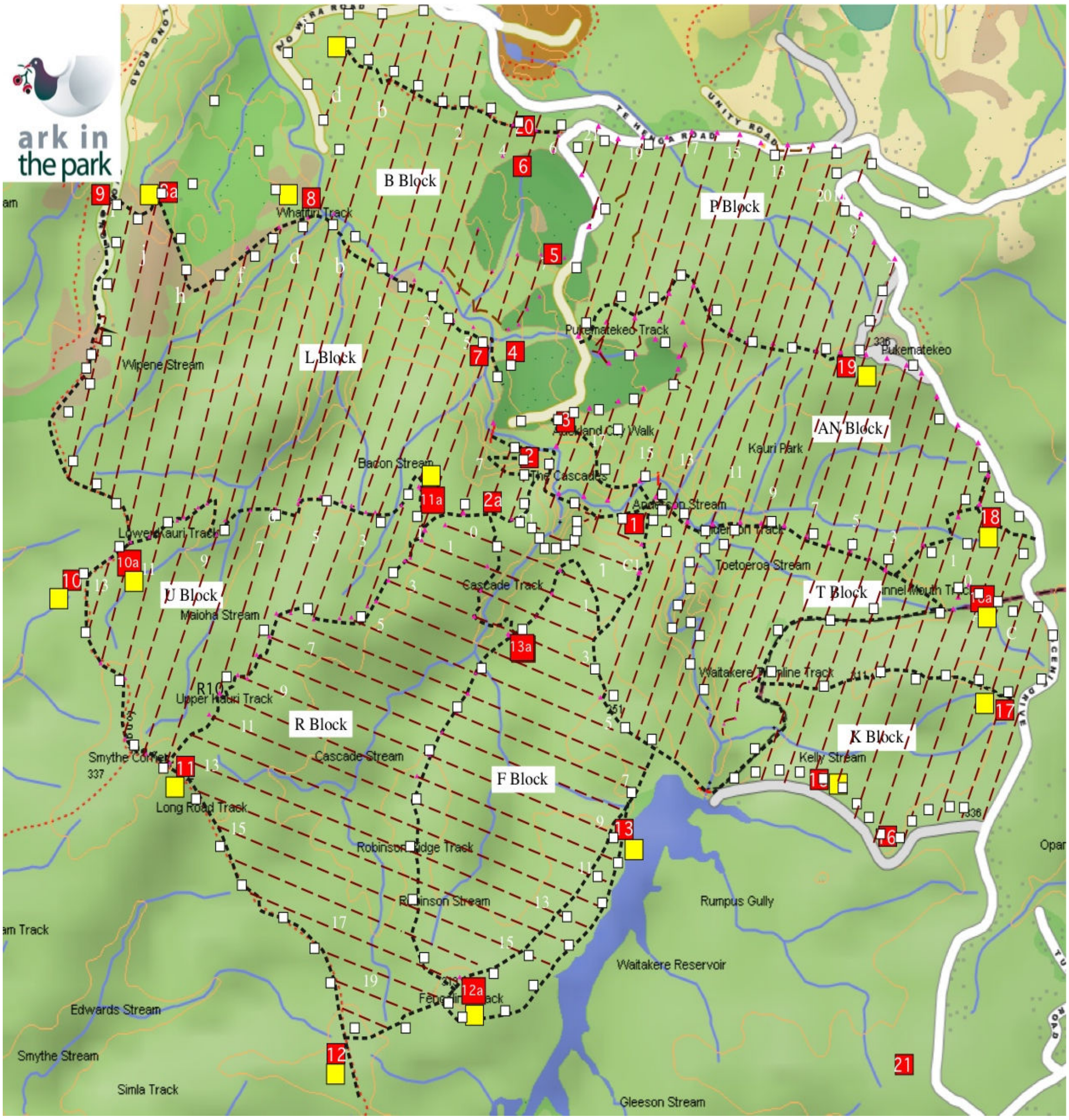

Figure 2.3 Existing AiP predator control layout, showing – – – – – bait lines, □ stoat traps, ■ cat traps, ■ tims traps, – – – – – – and main tracks. A 'Block' is and area as defined by a boundary formed by main tracks and/or roads. (Reproduced by permission of M Colgan, AiP).

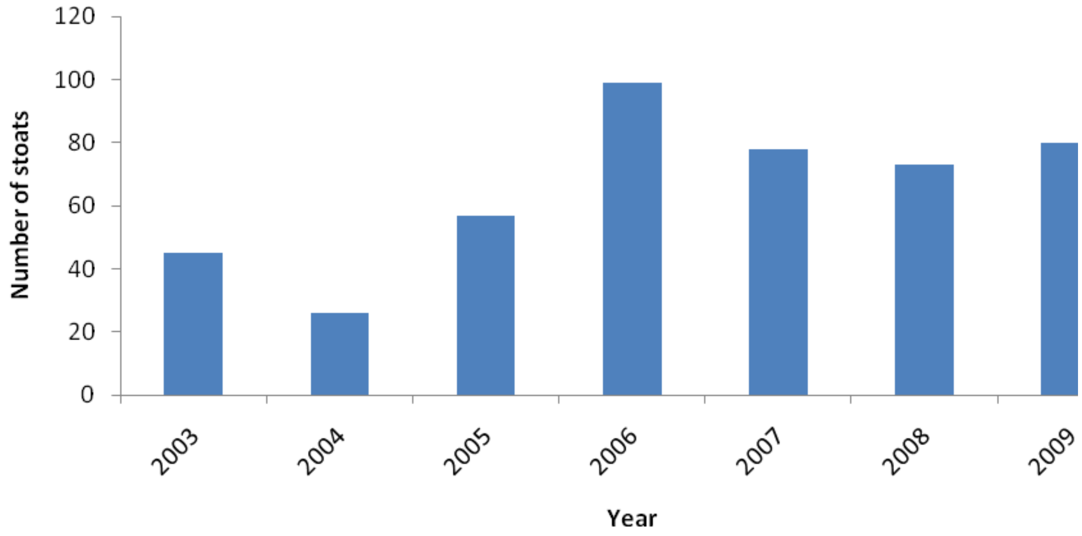

Figure 2.4 Total number of stoats caught in each year of the AiP operations.

The area of the Ark in the Park project has increased steadily since it started operations in 2003. The total number of stoats caught each year has not decreased. However, the total number of stoats per trap has decreased as the total pest area has grown, see Fig 2.5.

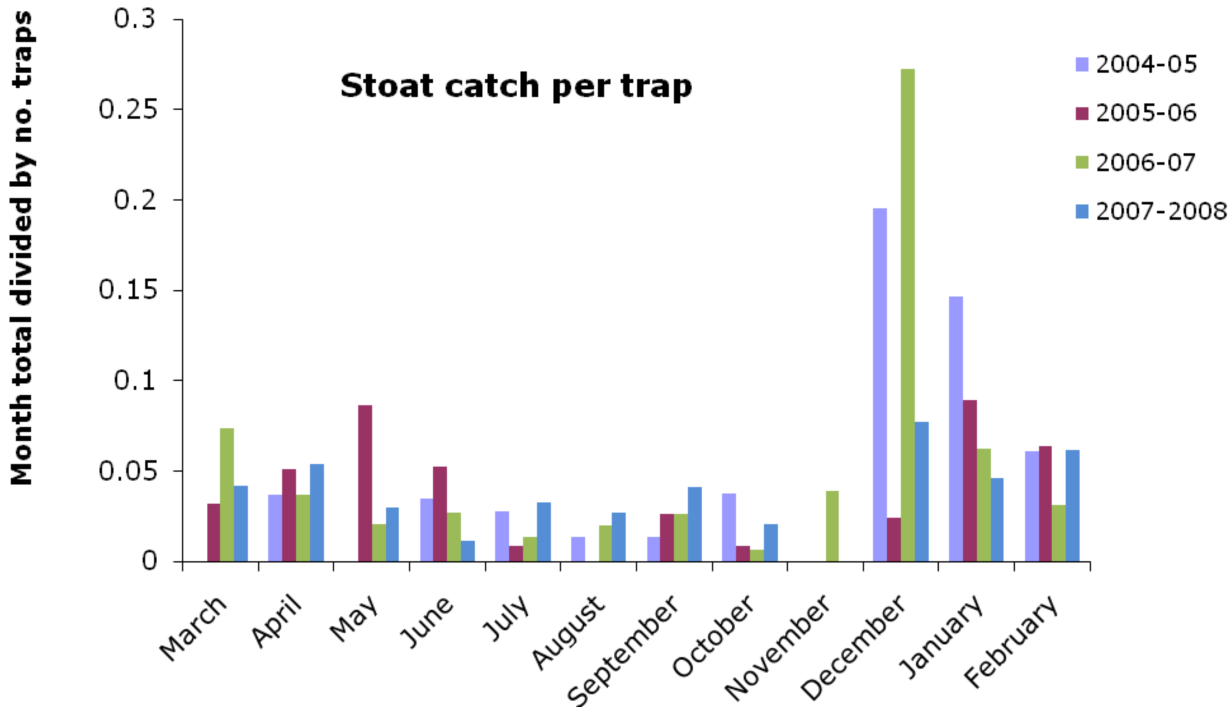

Figure 2.5 Total number of stoats per trap in the AiP since operations started in 2003. (Reproduced by permission of M Colgan, AiP).

Feral cat trapping is carried out over the entire area. Figure 2.3 provides an overview of the existing AiP pest controlled area, the layout of which is replicated in the research block. As the research block methods are based entirely on the AiP existing methods, the AiP methods are not documented here. Instead, the methods used for the research block are documented fully in sections 3.7 to 3.8, with any differences between the two clearly stated as such.

Historical data for the AiP.

Rat monitoring has been carried out at the AiP since its inception in 2004, two to three times per year.

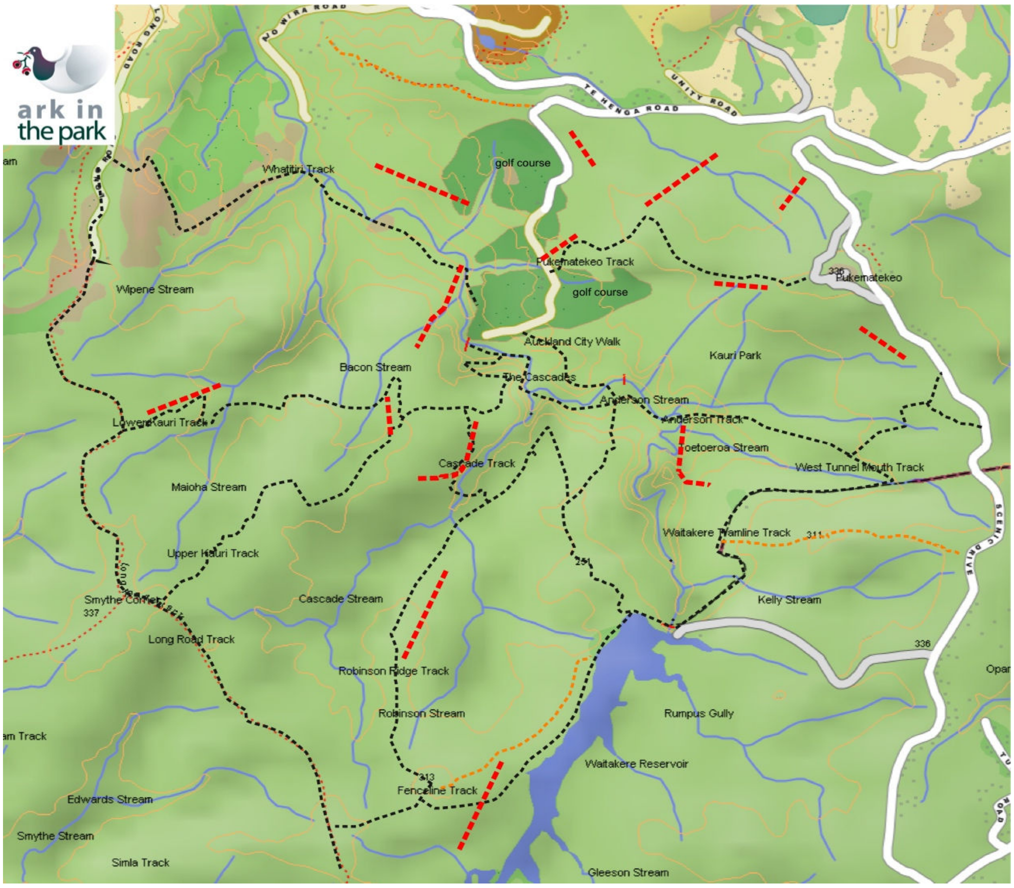

Figure 2.6 - - - - - **Rat monitoring in each block,** – – – – **main Auckland council formed tracks. (Reproduced by permission of M Colgan, AiP).**

The rat monitoring is carried out to the 'industry best practice' standards (Blackwell, et al., 2002), directing that one set of 10 rat monitoring tunnels be installed roughly every 100 hectares of pest control area,. This is described in full later for the Toxin Optimisation study. Records of rat monitoring data have been kept since the year before operations started on the ground at Ark in the park in 2002, see Fig 2.7. Data has been gathered since 2002, while pest control started in 2003.

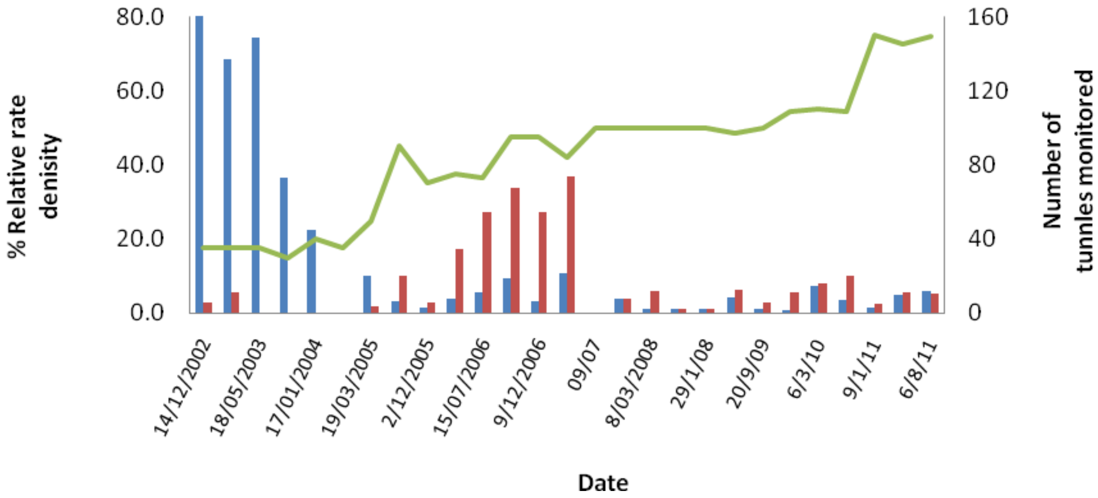

Figure 2.7 **Rat monitoring data showing relative density of rats dating back to the AiP inception in December 2002. Blue indicates relative rat indices, red indicates relative mouse indices. The green line indicates the number of monitoring tunnels that are checked, which has increased in number as the project has grown. Graph created from AiP archives.**

Notable milestones for AiP

The AiP project has met some notable milestones over its eight years of operation. Pest control measures implemented in the area have allowed four bird species to be translocated to the AiP project, including Whiteheads or popokatea *Mohoua albicilla* in 2004, North island robin *Petroica longipes* in 2005, Hihi *Mystis syncta* in 2007 and recently Kokako *Callaeas cinereai* in 2009 and 2010. Kokako, robin and popokatea are doing particularly well.

Research has become a routine part of the AiP project. Every year a number of international students spend three to nine months at the project for either field based experience or as interns. Study projects are carried out with the permission and assistance of AiP, and previous research includes work on Hihi (Richardson, 2009), moreporks *(Ninox novaeseelandiae)*, sound anchoring for kokako, and research on the Hochstetter's frog *(Leiopelma hochstetteri)* (Najera-Hillman, 2009). Research into New Zealand gecko and skink populations will commence during the 2010-11 season to investigate the animal's population density, home ranges and dispersal (Plate 2.1). Canopy studies have also been conducted by postgraduate students from Auckland University undertaking tree climbing training provided by the AiP project. Research into the native Giraffe weevil *(Lasiorhynchus barbicornis)* is underway at the adjacent F&B owned Matuku reserve (Plate 2.1). Kaka (Nestor meridionalis) appear to be present in the AiP in increasing numbers (Personal observation), and AiP are regular contributors to the national database for this species, www.kakawatch.org.nz (Plate 2.1).

Kaka (*Nestor meridionalis*) (location and photographer unknown).

Giraffe weevil (*Lasiorrhynchus barbicornis*) (location and photographer unknown).

Copper skink *(Cyclodina aenea)* at the AiP. (Photographer Marsha Leenan).

Pacific gecko *(Hoplodactylus pacificus)* in Forest Ridge adjoining AiP. (Photographer Daryl Munns).

Plate 2.1 Remnant native species populations present in and around the AiP area.

Hihi chick at AiP 2008-09 season (Photo author).

Hihi adult female unbanded at AiP 2008-09 season (Photo author).

Hihi juvenile at AiP 2008-09 season. (Photo Eric Wilson).

Popokotea on Tiri tiri Matangi. (Photo unknown).

Kokako at AiP 2010 season. (Photo Eric Wilson).

Toutowai at AiP 2008-09 season. (Photo Eric Wilson).

Plate 2.2 Native bird species translocated to the AiP since 2003.

Chapter 3 Toxin Reduction Study.

3.1 Background.

A study was undertaken to test if less toxin could be used in a landscape level pest control and habitat restoration project such as AiP and still achieve the required low level of rodent numbers. A research block of 333 ha was chosen east of the Waitakere dam. Contributing to the choice of this site was the dispersal into this non pest controlled area of the kokako; recently translocated to AiP. This research question is: “Can less toxin be deployed and achieve the same rat monitoring statistics already obtained by this successful conservation project, Ark in the Park?” To answer this question, one simple variation to the current pest control/management regime was trialled. The AiP project presently employs feral cat, mustelid and rat control. This research block followed the protocols used in the adjacent AiP area adjacent including the grid placement, toxin types, stoat and cat trapping on the main tracks and the monitoring method used to determine success. For the purposes of this research, only rodent control was altered so that a clear un-confounded study question could be answered. Rodent bait stations were spaced at twice the standard distance along the tracks hence resulting in approximately half the amount of toxin deployment. This chapter presents the methodological details of this study and the key conservation findings.

3.2 Method.

Research block layout.

The method presently used for rodent control at AiP and else where in New Zealand is a set of bait lines 100 m apart, installed parallel through the bush, kept as straight as possible beginning on main tracks and finishing on main tracks on the opposite sides of forest blocks (Fig 2.3). These varying sized blocks are managed as units with an integrated pest control plan for each block and group of blocks within a region. The AiP manage forest blocks within the Waitakere forest ecosystem. Bait stations were placed along bait lines at spacings of 50 m. The bait used to control rats is Pestoff©, Brodifacoum second generation anticoagulant. This bait reduction trial was achieved by increasing the spacing between these bait stations to 100 m. Around the perimeter, where reinvasion occurs (Mack, et al., 2000) a 150 m buffer is established where spacing is retained at 50metres between bait stations.

Plan Mapping.

Before any research commenced in the field, the entire area was mapped. This mapping was done using Geographic Information Systems (GIS) software.

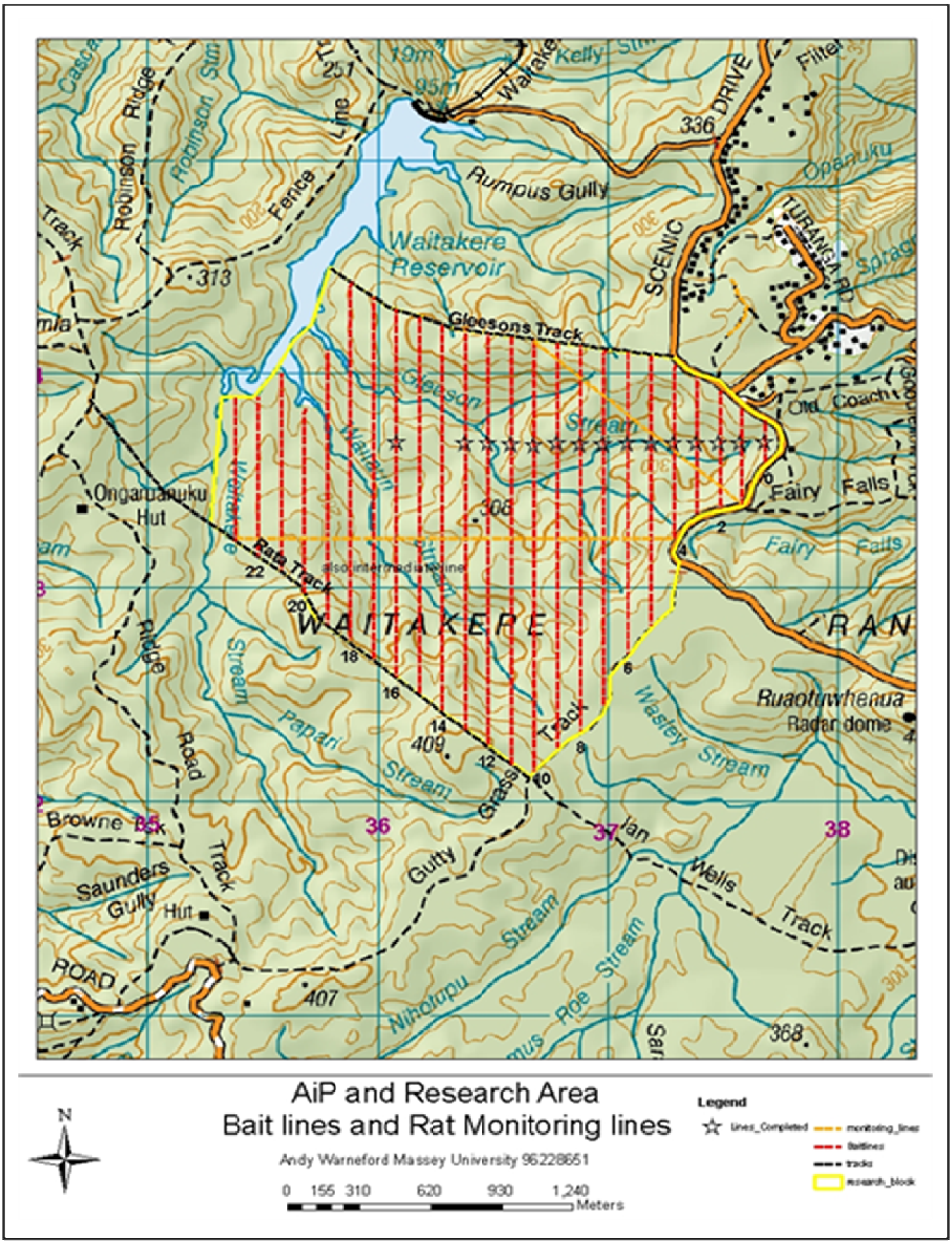

Figure 3.1 Plan map. GIS Map of the area indicating intended layout of the bait lines (red dashed lines). The perimeter of the research blocks is shown in yellow. The lines are numbered 1-23 east to west, which is the order in which they were installed.

One difference between the existing AiP area (Fig 2.3) and the research block (Fig 3.1) is that bait lines in AiP follow magnetic north-south or east-west headings, but in the research block the bait lines are on 'true' north-south headings. The correction is -21 degrees from magnetic to true. True (as opposed to magnetic) north-south grid lines were chosen. In doing this, Global positioning systems (GPS) units could then be used very easily and efficiently during the grid installation. The use of 'True' north-south navigation means that only either an easting or a northing coordinate needs to be observed on a GPS unit as a check of the uniformity of the installation while progressing. Thus, true north-south gridlines making installation of straight lines much easier in the field. The decision to do this eventually proved to be key to the projects outcome, and has since lead to further research, and results that were beyond the expectation of this project.

As-Built Mapping

As the research equipment was installed, GPS locations of all the equipment were saved so that accurate 'as built' maps could be produced (Fig 3.2). When 'plan' mapping is carried out, the map indicates what is 'intended' to be installed. Where 'as built' mapping shows exactly what 'has' been installed and includes all the modifications and adaptations that were required in the field to complete the installation. This may include the need to move stations or tracks to avoid damaging specimen trees, re-routing tracks around cliffs, or staying the minimum required distance of 20 m from waterways with bait stations. This minimum distance was requested by Watercare as part of the agreement with Auckland Council to allow this research in a water catchment area. Watercare is the administrative body responsible for all activities in the catchment for town water supply.

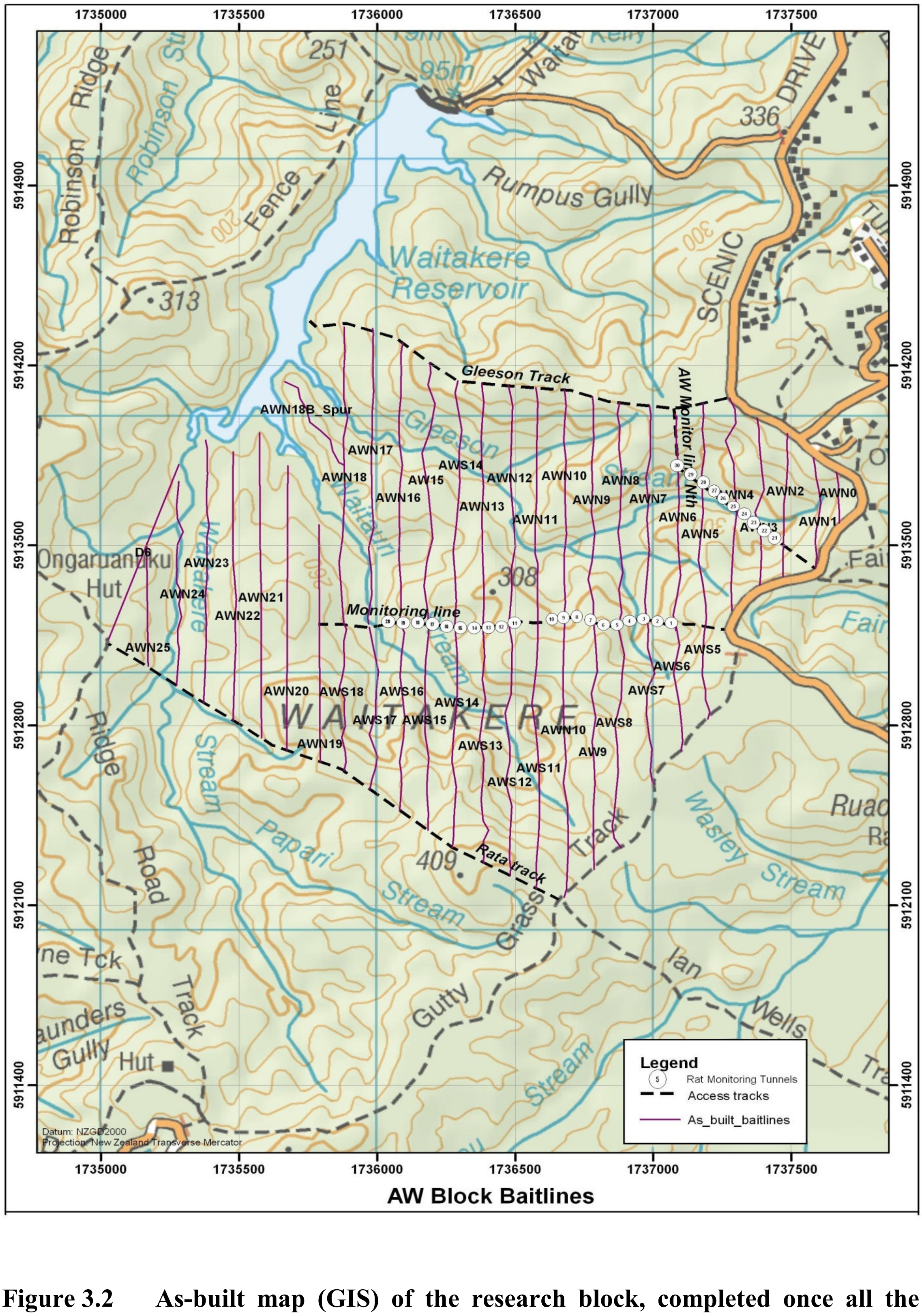

Figure 3.2 **As-built map (GIS) of the research block, completed once all the research equipment is installed. Red lines indicate the ‘actual’ path of baitlines, known from mapping the GPS locations of bait stations once they are installed.**

Accurate ‘as built’ maps are an important safety feature of the AiP project. All equipment, bait lines, major land marks and rat monitoring equipment are accurately mapped, with only the information required for each task shown on any given map to minimise confusion. This philosophy is repeated in the research block.

As built mapping is also a powerful tool in post research analysis. With the use of GIS software, ongoing data about the entire AiP bait uptake was recorded so that over time ‘hot spots’ (areas where more than half the bait deployed is taken) can be identified as areas where significantly more bait tends to be used. Additionally, ‘cool spots’ (where less than half the bait deployed is taken) might also be identified in the future, which might lead to further modifications of the baiting regimes presently employed, and those researched by this masters project.

Equipment used in the installation of the block.

Equipment was specifically purchased for the research installation, with several examples of each acquired so that multiple individuals could be fully equipped on any given day. Several teams worked over many months, so good quality gear was purchased on all occasions. All gear was fully numbered, engraved and had 200 mm lengths of pink marker tape attached to avoid the loss of valuable equipment in the field. The installation equipment included; Garmin Global positioning system (Garmin 60CXs), good quality compass, wolfgarten secateurs, silky bush saw sheathed, machete sheathed, hammer, black vivid marker pens, pen, trigene disinfectant in a spray bottle, 'no wasps' nest treatment, and radio tuned to ARC broadcast frequency (Plate 3.1).

Plate 3.1 Tools and equipment used during a day of installation work in the research block.

The personal equipment used for a day of installation work is the same as that used in the AiP project. This is also similar to that used by a well equipped hiker heading out for a full day of ‘on track’ tramping. This includes, tramping boots, large daypack, gaiters, water vessel, wet weather gear, first aid kit, over night emergency blanket, torch or headlamp, mobile phone and leather gloves (Plate 3.2).

Plate 3.2 Personal equipment used during day of work in the research block.

The rodent control and monitoring equipment installed in the research block is identical in make and design to the standard equipment used in the AiP project Equipment used included: Philproof® bait stations complete with lid, pink triangles, fencing staples 50 mm galvanised, 3'' nails, pink marker tape, orange marker tape, yellow marker tape, rat monitoring 'Black trakka' tunnels, and orange triangles (Plate 3.3).

Philproof® bait station attached to tree.

Bag of pre-bagged bait.

Bags fastened in lid.

Station set up with markings.

Black trakka tunnel and orange triangle in place.

Black trakka card with prints and peanut butter lure.

Plate 3.3 Rodent control and monitoring equipment installed in the research block.

Mustelid and cat control equipment installed in the research block.

Plate 3.4 Belisle trap and trap enclosure box at left, top right DoC200 and bottom right the Fenn6 and Philproof® cover.

The Belisle traps were used for cat control and imported from United States of America where they are used to catch badgers. It meets all Royal Society for the Protection and Care of Animals (SPCA) and National Animal Welfare Advisory Committee (NAWAC) guidelines. The enclosure makes the use of the trap safe for researchers, and also helps conceal unpleasant views of pest control from the public. Two forms of stoat traps were used: 1) DoC designed and built DoC200 traps (RSPCA and NAWAC approved) and 2) the Fenn Mk6 trap which. the AiP uses to target stoats (RSPCA approved, but no longer NAWAC approved). Both traps also kill rats, ferrets and weasels.. Fenn Mk6 are still available to the public, and widely used and, although DOC is currently phasing out the use of these traps, their high practicability, and comparatively low cost make them a favoured trap in the AiP project. Fenn Mk6 traps have proven to be effective on the target species, and a full record is kept of the kills at each trap site. No non-target species have been killed with the Fenn Mk6 trap at AiP. However, unfortunately three Hihi (one female and two males) were killed in the DoC200 traps. It is thought, that as these birds came from Tiritiri Matangi Island, they mistook the traps for nesting boxes. The construction and build materials of the DoC200 and Tiritiri Matangi nesting boxes are similar.

Installation technique.

Navigation.

The installation of pest control measures in the research block replicated the installation method in the existing AiP area. Referring to the map plan, the area was accessed using the local road and main track network. Scenic Drive (Fig 3.1) was the road primarily used for access, along with Dam Road, that leads to the Waitakere dam adjacent to the research block. The latter was used when carrying out work in the western areas of the block. The map plan shows main features, the roads and tracks which were used as navigation points to obtain the starting points for the bait lines. All grid lines started and finished on an 80 easting. For example, AW4 starts on E171580 N593919 at the northern end and finishes at the southern end on E171580 N593400. The next bait line into the block heading west is AW5 which starts on E171480 N593930. This means that as the installer travels north or south along the grid line, all they make sure the GPS easting does not change, and a relatively straight and accurate grid will be obtained. However, the installer must also be wary that this is an electronic system, using satellites to obtain the positional information. When under a forest canopy, some satellites will be obscured, even more so when in ravines or streams. Thus, the GPS operator must be vigilant at checking the ± accuracy displayed on the unit at the time. The installers developed a system of obtaining navigation points in the forest such as a tree or rock to navigate to. Checking this heading on their compass, the operator moves to the point and then rechecks their position on the easting of the GPS. The next navigation point would then be obtained using the compass, and so on. As already mentioned, practice and competence in this technique proved eventually to be pivotal to the success of the research as the spacings between grid lines was extremely consistent and reliable, and has resulted in further research into related topics.

The beginning and end of each bait line is double taped with pink marker tape. In addition, pink triangles are attached to the first tree on a bait line using fencing nails (Plate 3.5). If the nail is placed correctly then the triangle can be rotated so that it is perpendicular to the tree it is mounted on and hence more visible as the operator moves up and down the bait line. This avoids the problem of a triangle been nailed directly to the side of a tree, which makes it visible from one direction, but impossible to see from the opposite direction.

Plate 3.5 Bait station location marking showing double pink tape and triangle setup method.

Each block within the AiP project has a unique name. For example, the block adjacent to Pukematakeo track is called P block. Adjacent to the Anderson track is AN block.

Members of the AiP committee designated the research block for this study to be AW, the initials of the author. Thus the lines are numbered AW1, AW2 etc.

Each bait station then has a unique name also. The first part of this reflects the bait line name, and the second part reflects the number of the bait station on that line. Thus the bait stations are numbered AW1/1, AW1/2 on bait line AW1. On bait line AW2 they are numbered AW2/1, AW2/2 etc.

Physical installation of rodent control equipment.

The installation of the pest control equipment replicates the methods used in the existing AiP area as closely as possible. Bait stations are installed around 200 mm above ground level. They are attached using a nail and hammer. A spacer is included to allow the bait station to rotate freely for re-baiting purposes. Long nails (7.6 cm) were used, so that some tolerance can be left in the fixing of the bait station to allow the trees they are attached to room for growth. Bait stations first installed in the AiP area around 6 years ago, are now starting to experience 'stretching' of the equipment, due to tree expansion with growth.

Also, another important innovation of the AiP project that was incorporated in the current study is the use of the 'mouse ramp'. As can be seen from Fig 2.7, the rat monitoring carried out between 2005 and 2007 clearly shows an increasing presence of mice in the pest controlled area. It was decided in 2007 to add a 'mouse ramp' using fallen tree branch matter to make access to the bait stations easier for mice. Mice densities immediately dropped, and have not recovered (Fig 2.7). The mouse ramp innovation continues to be employed in the AiP, and so is incorporated in the research area.

Rat monitoring technique and installation.

The presence/absence of rats was established using a relative rat density measure. Black Trakka © tunnels were used, with Black Trakka ink cards inserted in them. Peanut butter was used as a lure (Plate 3.6). For every 100 ha of pest controlled area, one set of tracking tunnels was installed. The research block was 333 ha, so three sets of tunnels are present. Each tunnel is 50 m apart. Therefore we had three sets of tracking tunnel, each 450 m in length. Two sets ran through the core of the area (Fig 3.2) and the third line runs diagonally across the north eastern area of the research block. This third line is much closer to the perimeter, which installed in this way provides not only part of the overall data, but also data about what eventuates at the perimeter of pest controlled areas. A statistical control line is also installed in Spraggs bush walk, 400 m from the research area. The vegetation and terrain of this area is indistinguishable from the research block. All rat monitoring tunnels were marked with orange tape and triangles and individually numbered see plate 3.3 All tunnels were placed on as level a ground as possible so as to avoid rain damage, and the possibility of a card sliding out. The tunnels were fixed in place using the ‘horse shoe’ style pegs (Plate 3.6).

Containment of the bait within the bait stations.

The F&B owned reserve Matuku conservation group and reserve volunteers have a policy of ‘pre-bagging’ their bait prior to this being placed in the bait stations. Each small plastic bag contains around 150 g of bait pellets. It is believed this bait then stays dryer, more palatable for longer and is less likely to affect non-target species such as invertebrates and lizards. As with all new areas pest controlled in the AiP, two bags of bait are used in the initial baiting of this area. Placing the bait in small plastic bags also means that the lid that forms the base of the **Philproof®** bait station can be used as a clamp to stop the bag of bait being dragged out into the bush. It is hoped this is a further precaution against toxin entering the environment. The collar of the bag is simply trapped between the lid and the surround of the bait station. It also means that several pellets may be removed from the bait station, and the rest of the bait remains relatively dry and contained within the bag, which is in turn within the bait station.

Recording of data and information on the research block.

As already mentioned, technology was utilised where ever possible in the installation of equipment and the navigation of the study area. The use of GPS technology (Plate 3.7) meant that the location of all bait stations, bait lines, access lines and monitoring lines could be accurately added to maps using GIS technology. The contractors were trained in downloading the information directly to a laptop dedicated to the research (Plate 3.6).

Plate 3.6 **Contractors downloading information from a previous day's work before heading out again into the research block.**

Plate 3.7 **A Garmin GPS. Up to five of these were in use at any one time during the research collecting important information.**

Installation general overview.

The terrain in the research area is fairly typical of the Waitakere ranges, although not quite as mountainous as the existing AiP area. The vegetation is dense even by comparison to Little Barrier island and Kapiti Island New Zealand (Staniland, 2007). This made work in the research area difficult, demanding, at times dangerous but always adventurous. Fellow students were able to assist with the work, which provided employment through the ARC research grant. This also gave many individuals their first experience of paid conservation contracting, providing the opportunity to gain new skills and discipline. Around 25 different contractors were involved directly with the original research area and the resulting additional areas. At the time of the study we experienced a particularly hot dry long summer, which worked well for the research. The navigation of the bait lines, the physical installation of the equipment, placement of the bait, and bagging of the bait took around 4000 hours. Management of the project in the field was around 600 hours. As already mentioned, the area eventually pest controlled for this study was 333 ha. The team assembled for this study was also commissioned by ARC and F&B to carry our pest control of an additional 500 ha. This resulted in the AiP project being increased in total area from 1200 ha to a total of 2500 ha of pest controlled native forest ecosystem.

During the summer period while the research was carried out, 10-12 hour days were consistently worked by the contractors, so progress was relatively fast. However, when the study research area was completely navigated and installed, myself and the contractors were commissioned to carry out further work for ARC and F&B. This coincided with peak 'wasp season' in the Waitakere ranges (personal observation by author) resulting a down time of around one month. We recommenced work during late autumn, which meant day light hours were much shorter and progress was less efficient. The one way walk into the research area was around two hours giving an effective work time of around 4-5 hours. As can be seen, half of the paid time then is lost to accessing and leaving the area.

Grid layout general discussion.

The home range of *R. rattus* in kauri (*Agathis astralis)* has been shown to be around 174 meters, with no significant difference between male and female rats (Dowding & Murphy, 1994). This will no doubt vary from site to site, but roughly matches the scenario in the Waitakere ranges (Staniland, 2007). Analysis of the grid pattern is then needed to assess the reaction of a rat population to the installation of a grid rat management system (Fig 3.3).

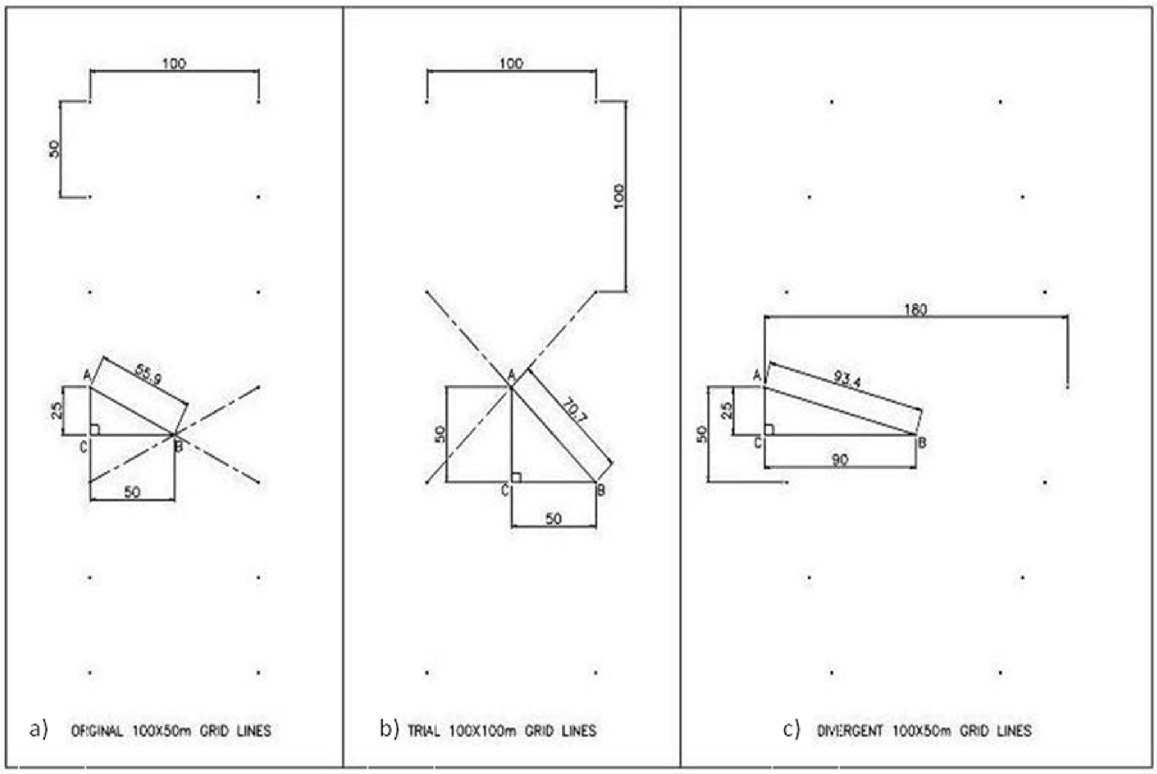

Figure 3.3 Comparison of different bait line grid layouts. The distance AB in the above diagrams represents the maximum distance from a bait station to any point within in a grid management system. The rows of dots represent bait lines, each dot being a bait station.

The distance AB in Fig. 3.3 represents the maximum distance from a bait station to any point with in a grid system. The 'Original' version (Fig 3.3a) is used in the existing AiP project, and the 'Trial' version is used for this project. The third version, 'Divergent' is an estimation of what occurs should bait lines not be installed accurately. This issue is referred to again in '4.4 Further Research' section of this thesis.

AB is found simply by using Pythagoras' theorem. For example, for the 'Original' grid system used in existing AiP project:

$$AB^2 = BC^2 + CA^2$$
$$AB = \sqrt{BC^2 + CA^2}$$
$$AB = \sqrt{50^2 + 25^2}$$
$$AB = 55.9m$$

This can be repeated for the 100 X 100 m grid, and also an approximation can then be made for a grid system, where the amount of 'divergence' is known, or even roughly known. Thus, the difference in maximum distance to a bait station within a 100 X 50 m grid as opposed to a 100 X 100 m grid is only ≈ 15 m. However, should the accuracy of a bait line within a grid system be poor for any reason, the maximum distance quickly increases (e.g. 'Divergent' Fig 3.3c).

Table 3.1 Maximum distance from a bait station to any point within the grid system of a managed area as measured on a plane (Fig 3.3).

a) Original 100 X 50m grid system	b) Trial 100 X 100m grid system	c) Divergent lines found as part of a 100 X 50m grid system
55.9m	70.7m	93.4m

There is a compounding factor to this issue. This analysis is being carried out on a flat plane, or a computer mapping system. However, the topography on the Waitakere ranges is steep and variable. This can be seen from the topography lines on the map of Fig 3.1

derived from Land Information New Zealand (LINZ). If the lines are ‘divergent’, as discussed above (Fig 3.3), then the topography of the area, particularly if severe will compound this, and the ‘actual’ distance between bait lines across the surface of the earth can quite easily reach 180-200 m. This has been found to be an issue in the existing Ark area, and is addressed further in the Discussion of this chapter.

3.3 Experimental design and statistical analysis.

Once the bait stations had been installed, rodent monitoring tunnels were installed in accordance with standardised DOC guidelines (Gillies & Williams, 2005). Thus, rat monitoring tunnels were installed at a rate of approximately 10 tunnels per 100 ha in the management area, resulting in 30 tunnels in total, and a spacing of 50m between each tunnel. It was decided to place the first 20 (M1-M20) of these tunnels more or less in the middle of the block to measure what densities resulted in the middle of the core. The core is defined as all the research area greater than 150m in from the boundary of the research area. Each of the three groups of 10 tunnels, are separated by a minimum of 150 m. The final 10 (M21-M30) monitoring tunnels were placed closer to the periphery. The periphery is defined by the band around the edge of the research block, 150 m wide, where bait stations are placed in a 100 X 50 m grid to try and limit reinvasion (Fig 3.4).

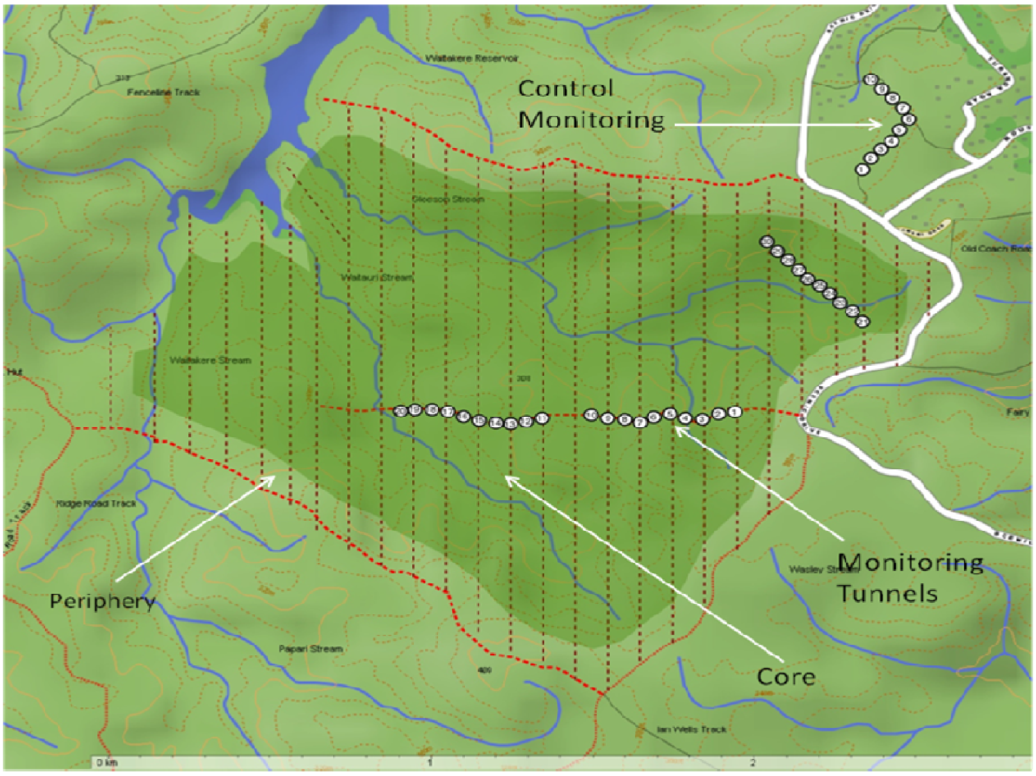

Figure 3.4 Layout of the research area, with 30 tunnels in the managed area, 20 of these (tunnels 1-20) being in the 'core' of the block, and 10 of these (tunnels 21-30) being closer to the periphery. 10 control tunnels are installed to the North-east, in Spraggs bush which is an unmanaged area.

The control line in un-managed area also comprised of a row of 10 tunnels. Once again the tunnels were each 50 m apart, and this unmanaged area was part of the same contiguous forest, but a little over 300 m away from the nearest point of the managed area. The density, complexity, maturity and composition of the forest was not discernibly different from the managed research area, being largely podicarp and broadleaf species (Staniland, 2007).

The tracking dataset was analysed using a logistic analysis (binomial response) with repeated measures (Proc GENMOD in SAS 9.1; SAS Institute, Cary, NC, USA). The presence/absence of tracks at each station within the experimental (M1-M20 - interior and M21-M30 - edge) and control (S1-S10) blocks was recorded at each of 6 time periods (repeated measures). The comparisons included experimental interior versus experimental edge and experimental versus control.

Confidence intervals were calculated for the relative percentage of rodents caught per trap using the online calculator at http://faculty.vassar.edu/lowry/prop1.html. This is based on methods described in (Newcombe, 1998) and (Wilson, 1927) (Table 3.2).

Pre-bait monitoring was carried out on each occasion the night before bait began to be put in the bait stations so the un-baited relative density could be assessed as accurately as possible. All tunnels were monitored one night only, including the control monitoring line, in accordance with national standard monitoring techniques (Gillies & Williams, 2005). The post-bait monitoring was carried out 3 weeks after all the bait stations had been baited. It was uncertain how long it would take for all the bait to be taken, but it was noted after the first baiting that all bait from bait stations had gone, by the time the second baiting had commenced. Conversely, it was also noted by the third and final round of the trial, that almost all the bait remained in the bait stations i.e. almost two full bags of 150 g of bait each. In most cases, the bags had not been opened or nibbled by the rats (personal observation).

3.4 Results

Rat monitoring data.

Rat monitoring was conducted from 13/11/2009 to 10/5/2010 at a total of 30 treatment monitoring stations and 10 control monitoring stations. The dataset contained no missing values. Tracking rates were significantly reduced following each baiting period and by the end of the study relative rodent density was lower in the core area than in the control area (X_1^2 = 10.89, ρ < 0.0001). The following graphs compare the results from the core of the study area and the periphery area combined, with the control line area (statistical control), and then the two are split to show the core and the periphery area separately compared to the non managed area.

Table 3.2 Confidence intervals for percentage relative rat density results. Pre-bait is monitoring done before a baiting, and post-bait is a monitoring following baiting.

	Managed area confidence intervals 95% intervals (Upper-Lower)	Unmanaged area confidence intervals 95% (Upper-Lower)
pre-bait 13/11/2009	63.3% (45.5-78.1)	50% (23.7- 16.8)
post-bait 22/11/2009	90% (74.4-96.5)	40% (16.8-68.7)
pre-bait 9/1/2010	43.3% (27.4-60.8)	90% (59.6-98.2)
post-bait 18/2/2010	6.7% (1.8-21.3)	60% (31.3-83.2)
pre-bait 6/4/2010	33.3% (19.2-51.2)	70% (39.7- 89.2)
post-bait 10/5/2010	3% (0.59-16.7)	80% (49.0-94.3)

Table 3.3 Rat monitoring results 13/11/2009 to 10/05/2010. Rat monitoring results using black tracker tunnels with peanut butter as lure. All monitoring was carried out on fair to clear nights. 1 indicates presence of rats, 0 indicates no presence.

	pre-bait 13/11/2009	post-bait 22/11/2009	pre-bait 9/01/2010	post-bait 18/02/2010	pre-bait 6/04/2010	post-bait 10/05/2010
Managed						
M1	1	1	0	0	0	0
M2	1	1	1	0	0	0
M3	1	1	0	0	0	0
M4	1	1	0	0	0	0
M5	1	1	0	0	0	0
M6	1	1	0	0	0	0
M7	1	1	1	0	1	0
M8	1	1	0	0	0	0
M9	1	1	0	0	0	0
M10	1	1	0	0	0	0
M11	1	1	0	0	0	0
M12	0	1	0	0	0	0
M13	0	1	0	0	0	0
M14	1	1	0	0	0	0
M15	0	1	0	0	0	0
M16	0	1	1	0	0	0
M17	0	0	1	0	0	0
M18	1	0	0	0	0	0
M19	0	1	0	0	0	0
M20	0	1	1	0	0	0
Tunnels M1-M20 % relative rat density	65	90	25	0	5	0
M21	0	1	0	0	1	0
M22	1	1	1	1	1	0
M23	0	1	1	0	1	0
M24	0	0	1	0	1	0
M25	1	1	1	0	1	0
M26	1	1	1	0	1	0
M27	0	1	1	0	1	0
M28	1	1	1	0	1	1
M29	1	1	1	0	1	0
M30	1	1	0	1	0	0
Tunnels M21-M30 (closer to periphery) % relative rat density	60	90	80	20	90	10
Total managed area % relative rat density	63.3	90	43.3	6.7	33.3	3.3
Control Unmanaged						
SB1	0	0	1	0	0	1
SB2	0	0	1	1	0	1
SB3	0	0	1	1	0	1
SB4	0	1	1	1	1	1
SB5	1	0	1	0	1	1
SB6	1	0	1	1	1	0
SB7	0	0	1	1	1	1
SB8	1	1	1	1	1	0
SB9	1	1	1	0	1	1
SB10	1	1	0	0	1	1
Tunnels 1-10 % relative rat density	50	40	90	60	70	80

Toxin usage data.

When bait stations are first baited, the relative rat densities are at their highest (Table 3.3) and all the bait placed in the bait stations at this time is taken quickly (personal observation). A direct comparison of this initial bait uptake can be made between the research area, and an existing area of the AiP project. The closest existing managed area was chosen as a comparison, which is approximately 250 m away at the nearest point, and of similar habitat (Staniland, 2007).

Table 3.4 Comparison of existing Fenceline block (F block) as part of the AiP managed area vs the research block (AW block).

	Area in hectares (ha)	Total number of bait stations	Number of bait stations per ha	Amount of bait per ha in grams	Total cost per ha including bait and stations ($)	Reduction in bait per 100 ha in kilograms	Savings per 100 ha
Fenceline block (F block)	103	233	2.3	690	25.07		
Research block (AWN block)	333	467	1.4	420	15.26	27	981

The reduction in bait per 100 ha of managed area is approximately 27 kg (Table 3.4), but the total reduction in cost is $981 per 100 ha (Table 3.4). This is because the cost of bait per bait station is less that $1, whereas the cost of a single bait station to the project is $10 each, although the latter is a one-time cost. Labour costs are not included here, as the difference between the two systems in this regard is minimal, inconsistent and difficult to quantify.

Rat monitoring data.

Rat monitoring data of the entire research area includes both the core area (tunnels 1-20) and also the monitoring tunnels closer to the periphery (tunnels 21-30). The monitoring carried out in the study area prior to any pest control showed a relative density of 63.3% presence, with the control monitoring in the non pest controlled area showing a relative density of 50% presence. After three rounds of baiting the study area showed a relative density of 3% presence while the control area showed 80% presence monitored at the same time.

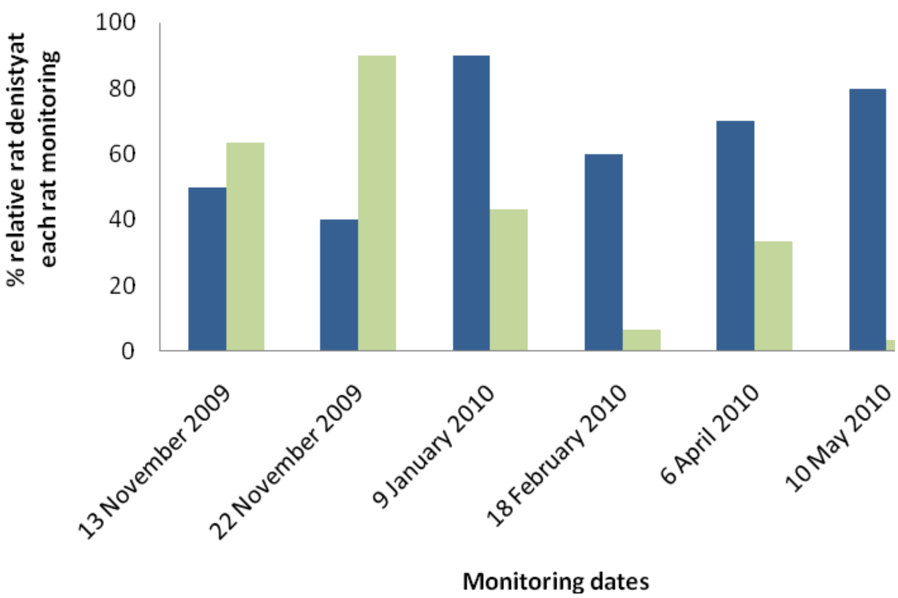

Figure 3.5 Rat monitoring results carried out before and after each of the three baiting rounds. Blue shows data from the control line in the non managed area, and grey shows data from the managed area, including monitoring from both the middle of the core area and monitoring from closer to the periphery.

Rat monitoring results carried out in the middle of the core of the managed study area (tunnels 1-20 of Fig 3.3) showed that after two rounds of baiting relative rat density fell to 0% presence. It climbed again to 5% presence before the third round, but again fell to 0% presence after the third round. During the entire study time of 13 November 2009 to 10 May 2010, the relative rat density in the statistical control block (non pest controlled area) rose from 50% to 80% presence.

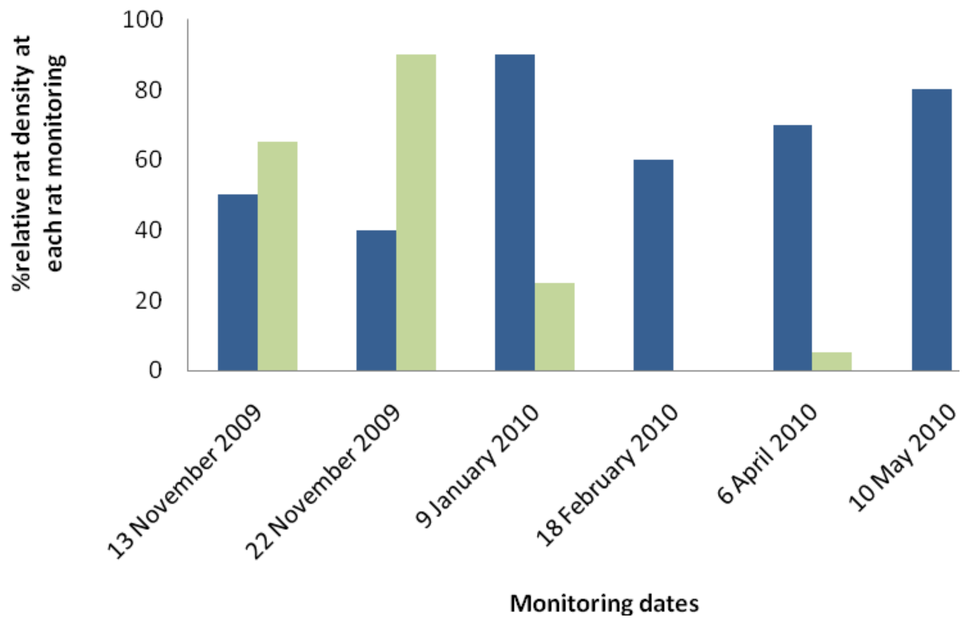

Figure 3.6 Rat monitoring results carried out in the core of the pest controlled study area carried out before and after each of the three baiting rounds. Blue shows the control monitoring of the non managed area and grey shows the managed area results from tunnels.

Rat monitoring closer the periphery showed a relative rat density of 10%. However, from the bait cards it was noted that there was only the presence of one single rat, with one set of prints entering the monitoring tunnel, and one set exiting the monitoring tunnel. All of monitoring cards during the rest of this research showed many sets of prints, with cards in most instances being completely covered in prints, both entering and exiting.

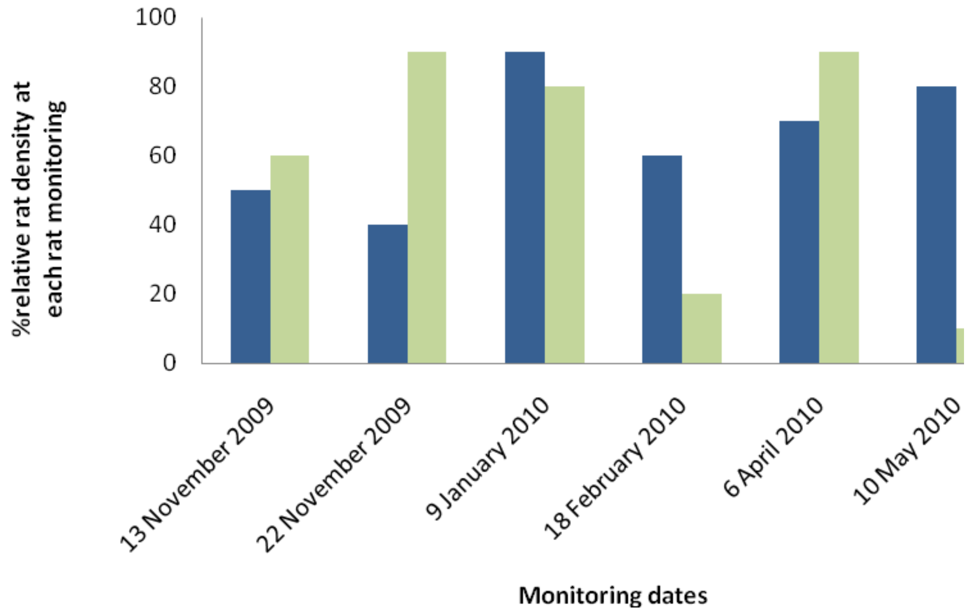

Figure 3.7 Rat monitoring results carried out in the core, but closer to the periphery of the managed study area (tunnels 21-30 of Fig 3.3) before and after each of the three baiting rounds. Blue shows the control monitoring of the non managed area and grey shows the managed area results from tunnels.

3.5 Discussion

The baiting regime of 100 X 100 m spacing appeared to achieve the required relative rat density in the core area after just two baiting cycles, but on the peripheral relative rat density stayed at a higher than required level. Rats are known to reinvade areas quickly following pest control operations (Russell, et al., 2009) and risk of reinvasions from surrounding areas lacking pest control is likely to remain high. However, monitoring a year after this research was completed shows the peripheral or buffer zone did achieve an affective density of 0-3% (personal observation).

The statistical control block showed a marked increase in relative density for the study period, going from 50% to 80% rodent presence for monitored stations. In addition it should be noted that the number of rat prints on the tracking cards varied over the period of the study. Although, the relative rat density in the study area before pest control commenced was 63.3% and after was reduced to 3% overall and 0% in the core, the monitoring stations also had different levels of track activity across the study period. During initial monitoring it was clear that many rats (based on size and shape of the prints) had entered monitoring tunnels that showed a presence. However, by the end of the study, the one card that showed presence for the entire research managed area had one set of prints across the card. This indicated the presence of only one rat at that monitoring point. This conservative approach to estimating rodent density using tracking cards is likely to underestimate rodent densities for both high and low density rodent populations.

Changing the configuration of the rodent management grid system to 100 X 100 m has shown that varying spatial deployment can achieve the required relative density needed to reach biodiversity goals. By employing this system, a significant reduction in cost per ha was achieved, and the amount of toxin used for the initial knock of rats was reduced. However, further analysis of the grid has shown that the precision and thus straightness of lines is paramount to its success. Deviations from straight parallel lines, compounded by steep and extreme terrain, are likely to result in gaps in the system that permit rodent populations to persist. It is known that the small home ranges of some rats (Davis, et al., 1948; Harrison, 1958; Dowding & Murphy, 1994; Tobin, et al., 1996) can result in a few individuals surviving within the distances between bait lines and bait stations, but when lines diverge due to inaccuracies and terrain, this number can increase and lead to residual embedded rat populations (McGregor, Unpublished data). Recent research has shown that one mitigating factor to this may be that as densities decrease, home ranges tend to increase in size (Innes, 1977; Innes, 1990; Hooker & Innes, 1995; King, et al., 1996).

With having less bait stations per ha, the amount of toxin used may be reduced. To establish this accurately a longitudinal study would need to be carried out that compares 100 X 100 m to a 100 X 50 m grid system in actual bait usage. The study would need to be conducted over sufficient time to allow testing across of the various grid systems in relation to seasonal variation, food abundance variation including yearly differences such as mast years (or at least the broadleaf equivalent of), variation of predator numbers and varied times between baiting which occur for logistical reasons.

Clearly the behaviour in terms of foraging preferences and food caching, home range size and variability, sociability and movement responses to population density will all have an impact on both how much bait is removed from stations and how many stations may be visited by a single rodent. Much of this information is un-researched and unknown. For example it is not known if individual rodents 'guard' bait stations and exclude conspecifics or other rodent species from taking the bait. It is also not known whether individual rodents visit multiple stations or use cues from each other about bait locations. Future research is required to address these deficiencies in current knowledge of wild rodent behaviour and dispersal ecology.

Finally, regardless of whether increasing bait station distances has an effect on the amount of the poison that enters the environment, the toxins required for the initial baiting of the grid is less due to fewer bait stations in a given area. Typically all bait is removed from stations during the initial bait session, regardless of the spacing of the stations.

Chapter 4 Conclusions, recommendations and future research directions.

Introduction.

Many anthropogenic effects and occasional human predation have no doubt had huge and ongoing effects on the biodiversity of Aotearoa New Zealand (Lal, 1993), but the single biggest factor influencing New Zealand's biodiversity decline is rats (Towns & Daugherty, 1994; Burney & Flannery, 2005). However, control of rats is possible (Innes, et al., 1995; Towns & Broome, 2003; Hoare & Hare, 2006; Howald, et al., 2007) and is considered fundamental indeed critical to the recovery of many species, from endemic shore skinks *(Oligosoma smithi)* to New Zealand species listed as range restricted by the IUCN to kokako and invertebrates including the Mahoenui giant weta *(Deinacrida n. sp.)* (Clout, et al., 1995; Eason & Spurr, 1995; Empson & Miskelly, 1999; Innes, et al., 1999; Powlesland, et al., 1999; Towns & Broome, 2003; Wedding, et al., 2007; Howald, et al., 2010). One of the most prevalent and effective methods of controlling mammalian pests such as possums *(Trichosurus vulepcula)* and rats is through the use of poisons (Clout, et al., 1995; Powlesland, et al., 1999). However, the use of toxins in the environment does have consequences such as secondary poisoning mortalities and potential toxin build in the food chain. Therefore toxin use needs to be optimised both in quantity used and frequency and the location it is applied. (Eason & Spurr, 1995; Eason & Spurr, 1995b; Ogilvie, et al., 1997; Murphy, et al., 1998; Empson & Miskelly, 1999; Gillies & Pierce, 1999; Innes & Barker, 1999; Stephenson, et al., 1999; Eason & Lincoln, 2002; Eason, et al., 2002; Booth, et al., 2003; Craddock, 2003; Fisher, et al., 2003; Hoare & Hare, 2006; Wedding, et al., 2007; Eason & Ogilvie, 2009).

Refining the methodology for effective pest control protocols was a central goal of this thesis. Testing of toxin effectiveness can be conducted in the laboratory under controlled conditions but the true test is the experimental application of toxins at a scale in the environment comparable to real life situations faced by conservation managers (Sotherton, 1998). In my study the area used for was 333 ha, with an additional 900 ha being pest controlled and managed using the protocols trialled here. Experiments on such a scale are seldom achievable and this opportunity came about due the rigorous approach to pest control. This large scale project operating in an area totalling more than 1200 ha, with a legacy of some six years of data, affords a research opportunity that allowed comparisons of different amounts of toxin application in both a longitudinal study and over a large physical area.

Using the 'Ark in the Park' project as a model, this toxin optimisation study reduced usage for a given area by almost half, and achieved even lower relative densities of rats than the existing process. This entire process took around six months and the use of 20 contractors required for implementing the study (navigation, installation, marking, clearing bait lines and access lines and re-baiting). In this thesis, I have examined whether taking a standard technique for large scale pest control and modifying it to significantly reduce toxin use can work to control rodent pests. An existing, long standing and successful conservation area was used as a model, and an area of 333 ha immediately adjacent to this group was used as a research block. Relative rat densities from this research block are currently 0-3% (Figure 4.2). This area was then incorporated into the existing conservation predator/pest controlled area.

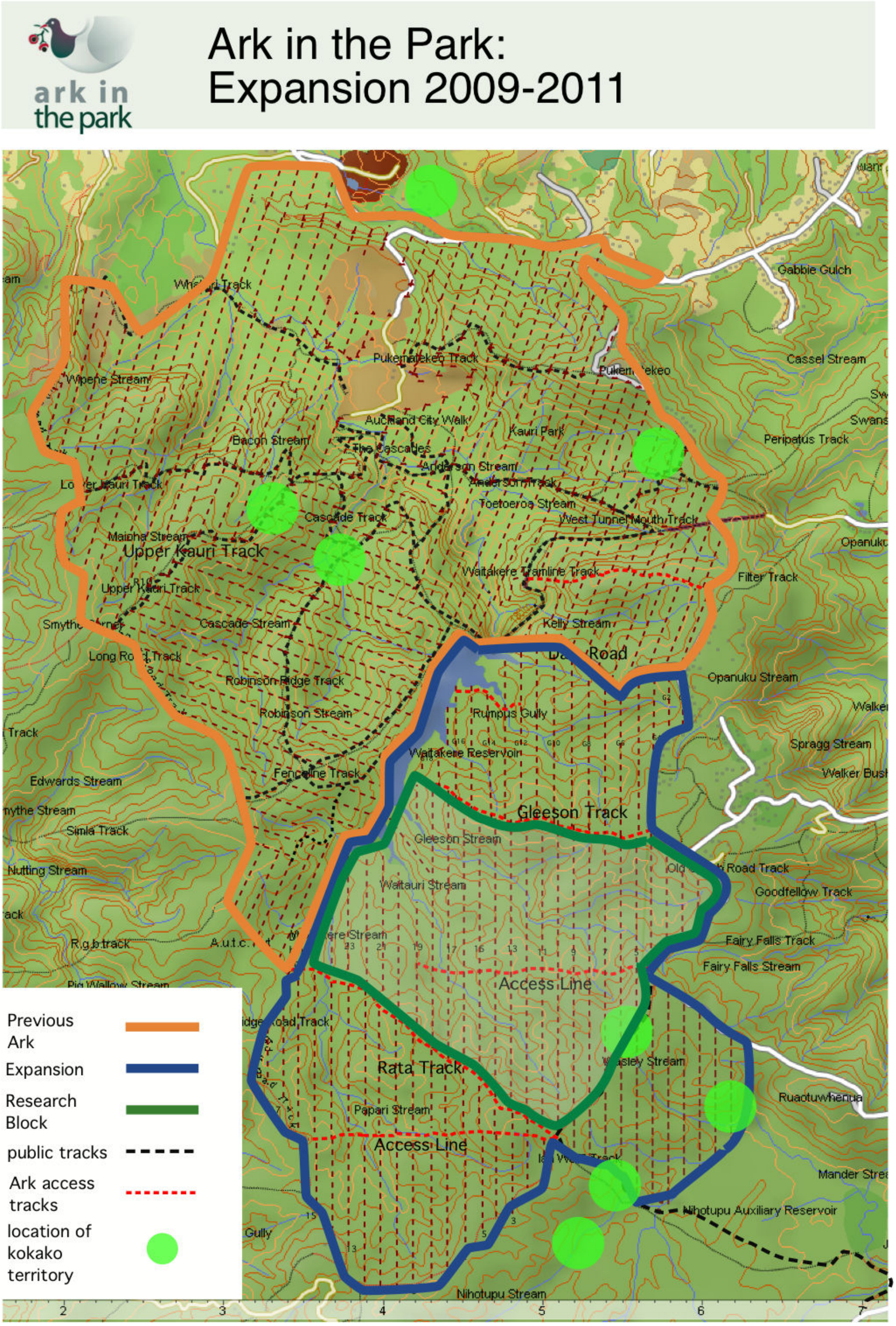

Figure 4.1 Present Ark in the Park managed area, showing the research block shaded and subsequent additional areas resulting from this research (Reproduced by permission of M Colgan, AiP).

An unexpected finding from the new toxin reduced research area was that rat densities reached were even lower than those achieved by the original project. Why were rodent densities lower despite less toxin being used?

Comparison of the different bait line layouts demonstrated that lines in the original area which were manually (compass) placed were in fact less accurate than the GPS position lines in the experimental area. Given the perfect placement of parallel lines within a grid, the maximum distance to a point within a grid system from a bait station only increases by around 15m, when comparing a 100 X 50 m grid to a 100 X 100 m grid pattern (Figure 3.3). However, when bait lines are placed with less accuracy some (lines closer other further apart) then the maximum distance can increase: in this case to more than 90 m, an increase of 35 m compared to the 15m increase mentioned earlier. Given the documented home ranges of *R. rattus* (Dowding & Murphy, 1994), this increase in maximum distance to a bait station could be a cause of residual rat populations within many grid management systems.

To examine this problem further I worked with a final year undergraduate student to address the question of 'divergent' bait lines and the possible compounding factors of topography, see below. The research question was "Can divergent bait lines harbour residual rat populations within a pest management grid system?" We examined maps based on 'real world coordinates' of bait stations, particularly in the older 'Ark in the Park' managed area. These lines were installed when modern technologies such as Global Positioning Systems (GPS) and Geographic Information Systems (GIS) were not readily available to the installers of bait lines. Lines were installed using compass bearings and magnetic headings. However, a GPS was used to establish start and end points of the lines. Thus, the precision and accuracy of these lines across mountainous terrain and thick vegetation (Staniland, 2007) could not be checked or verified at the time. When assessed using GPS technology some lines were in fact divergent (see Fig 3.3). Often, this divergence was due to steep terrain such as bluffs, ravines and cliffs , or dense vegetation being encountered (Sumich, 2006). Once it was established that some lines were divergent, we then considered what impact the terrain might have on these lines, as to the distance across the surface of the earth. An analysis of this was done using basic trigonometry (Fig 4.1).

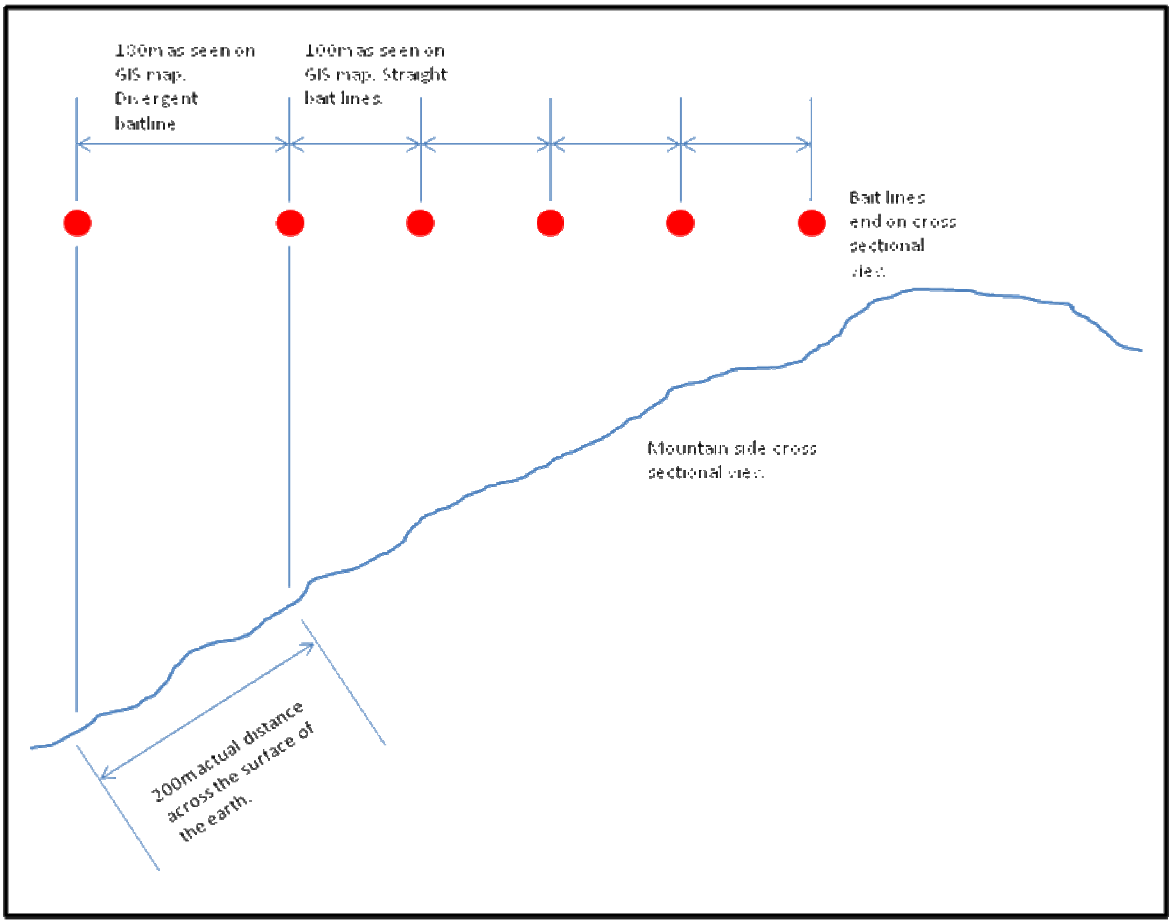

Figure 4.2 **Cross sectional view of mountainous terrain, with baitlines running along it toward the point of section. Each red dot represents the end on view of a bait line at the point of cross section.**

As seen in Figure 4.1, the actual distance across the earth's surface is not the same as seen on GIS, or across a flat plane such as a map. In fact, further compounding this are localised undulations in the surface as also shown on this diagram and the 200m 'actual' distance depicted in Fig 4.1is a straight line and hence underestimated distance. Finally, the vegetation on the surface also increases the distance travelled by rodents to reach a bait station (Staniland, 2007). Arboreal dwelling rats could add further distance between themselves and a bait line due to vegetation height. All these factors contribute to create 'holes' within the grid system where residual embedded rat populations could live.

At the conclusion of this study, approximately nine months of data have been gathered from these 'holes' between bait lines. These data have shown 40-90% relative rat densities in these 'hole' areas. These levels are typical of rodent densities reached in the non-managed control lines for the project area (50-60% relative rat density). The higher rat density of the 'Embedded Rat Populations' is possibly due to improved habitat and reduced predator numbers resulting from to pest control management of surrounding areas. The rat monitoring of the existing Ark in the Park areas with a 100 X 50 m grid is typically 0-15% presence. The monitoring in the research block two years following installation (and the subsequent areas totalling 1200 ha) continues to produce 0-3% rat presence at the time of completion of this research. It should be noted, the lines in the newly managed areas are not only significantly straighter, but also the topography is less extreme in these new areas (Figure 4.2).

4.1 Recommendations.

- Continue to operate the research block as a managed area, using the protocol that was trialled.

It is recommended that the study area where the 100 X 100 m grid was trialled, continue to be baited using this regime. While the initial results from this study show promising results for rat control using less toxin, and a wider spaced grid, the long term effects of this less intensive pest control protocol is not known. For the purposes of the trial, the area was re-baited three times within a relatively short period of only 6 months. Although the results of this were very good, it obviously does not take into account the differences in food and predator abundance that occurs from year to year.

- Continue to observe the results as a longitudinal study.

I suggest that for at least the next two years rat monitoring results for this area be carefully observed, and signs and trends of relative rat density be analysed. Differences in conditions, such as weather, food abundance and predator abundance, and the resultant rat populations can then be observed, and thus the efficacy of this new strategy to deal with those fluctuations can be assessed.

- Expand the managed area using this protocol.

I also recommend that new areas to be pest controlled as part of the Ark in the Park region be pest controlled using this protocol. This will provide more data to make comparisons across a variety of areas and habitats, so the any unforeseen issues or problems can be addressed. Varying terrain is potentially animportant factor: can low toxin use work in steep and variable terrains? As new areas are controlled and managed using this protocol, the impact of varying topography on the efficacy can then be assessed.

- Move to year round management.

The present philosophy for the pest control in this part of the ranges is to target the bird breeding season, October through February, yet the historical data for the project shows rat numbers will climb over autumn without pest control. This places bird species that roost or take refuge in cavities such as hihi at particular risk. Other biota in the area such as invertebrates, lizards and aquatics are at risk all year round from rats. If eco-system restoration is to be achieved as opposed to avian protection, then year round abundance must be controlled.

4.2 Future research directions

- Different grid patterns and distances.

The data from this study show that alternatives to standard pest control techniques might work in the short term. However, a variety of different patterns could be considered, e.g. 100 x 100 m grid, variable grid spacing dependent on the topography and vegetation, and different temporal patterns of baiting.

- Different types of toxins and poison agents

I also believe it is very important to trial alternative bait types. Concerns have been raised about the ongoing use of Brodifacoum in any one area. These concerns not only relate directly to the target species, but also to non-target species, where the persistence of Brodifacoum has caused concern. Having said that, much of the evidence on this issue has been gathered opportunistically, and empirical evidence on this issue, especially over longer periods is scarce. This is perhaps one obvious area of research that needs further attention, and the Ark in the Park project provides an ideal platform of opportunity for this given their long term use of this toxin.

- Further investigate the persistent nature of toxins

Related to the previous recommendation is the need to further research on the build up of Brodifacoum in invertebrates, particularly those collected in areas adjacent to bait stations. Invertebrates metabolise Vitamin K differently to vertebrates, allowing them to feed on the agent and not be affected. However, they in turn could be an indirect source of Brodifacoum to species higher up the food chain.

- Effects of toxin and benefits of pest control on different aspects of the ecosystem.

It would be interesting to know what affect pest control in AiP is having on aquatic life. No studies in this area have yet been undertaken, even though numerous species are present in the AiP such endemic frogs, Longfin (*Anguilla diefenbachii Gray*) and Fresh water crayfish or Koura (*Paranephrops spp*). It is also not known whether any residues or build up of toxins have occurred in these species.

- More detailed information on rat populations and abundances.

Further studies that show the absolute abundance of rats in the AiP area should be carried out. The only measure of the effectiveness on the pest control is rat monitoring to measure relative density. Little is known of the actual density of rodents per ha or how this varies seasonally or annually.

- Other measures of biodiversity.

The focus of this project has largely been on measuring the benefits of pest control for avian species, and the re-introduction of these. However, as mentioned earlier many other biota exist in the managed area and consideration to benefits/consequences for these other species should be afforded further investigation. Invertebrates are monitored using pitfall traps systems, gecko numbers are now being assessed, and some frog species receive some monitoring but beyond this, little is known of the total biodiversity of the area, and its reaction to pest management programs.

- Management of different types of forest and ecosystem situations.

Fragmented blocks of bush provide special challenges to pest control managers. The method studied here could be trialled in a fragmented block of forest. However, I believe the buffer at the peripheral may need to be intensified i.e. more bait stations, to alleviate the effects of reinvasion from non pest controlled areas.

4.3 Summary

Restoration of New Zealand's biodiversity requires not only an understanding of the habitat requirements of our native species but also the implementation of pest control techniques that: 1) minimise by-catch, 2) reduce implementation and maintenance costs, and 3) are acceptable to the New Zealand Public. This project took a pragmatic view that the use of toxins to control rodents is a 'necessary evil'; currently conservation practitioners in New Zealand have no effective alternatives for large scale pest control. We are obliged to look at ways of reducing toxin use. The findings from this project confirm that less toxin distributed within a more precise grid can be equally, if not more, effective compared to standard baiting protocol. More widespread implementation and testing of the protocol suggested here will help find an optimal minimum of toxin for pest control in a variety of habitats.

Appendix I Permit for research on ARC administered parkland.

20 October 2009
Andy Warneford
MSc Candidate
Institute of Natural Resources – Albany Campus
Massey University
Private Bag 102904
North Shore Mail Centre
Auckland
094140800 ext41197 or 02164485
andywarneford@orcon.net.nz

Dear Andy Warneford

Permit to undertake research in the Waitakere Ranges Regional Park.

Thank you for your application to undertake research on animal toxin optimisation within the Ark in the Park project in the Waitakere Ranges regional park land. The Auckland Regional Council grants you permission to undertake your proposed research, subject to the conditions outlined below:

Specific objectives for study:

1) To reduce the set-up and ongoing cost of rodent control within the Ark in the Park project area.
2) To examine the animal toxin baiting density required to control rodents to less than 3% presence measured by standardised tracking tunnel monitoring.

Study Sites:

1) Waitakere Catchment – Cascade Kauri Park

This includes two blocks (L and P Blocks) where rodent control is currently undertaken by the Ark in the Park organisation, and expansion into a new site where rodent control has yet to be implemented (east of the Waitakere Dam). All sites are within the Ark in the Park project area established in the Memorandum of Understanding between the Auckland Regional Council and the Forest and Bird Protection Society (sponsor of the Ark in the Park project).

Approved Activities:

1) Removal of Pestoff animal toxin from every second bait station within the existing rodent control areas.
2) Navigation and marking with pink flagging tape pest lines (100m part) and blue flagging taoe rodent monitoring lines within the new site
3) Installation of plastic markers and Philproof bait stations at 100 metre intervals along the new pest lines. The bait stations will remain in place at the completion of the research for use by the Ark in the Park project.
4) Installation of rodent monitoring tunnels which will remain in place at the completion of the research for use by the Ark in the Park project.
5) Light trimming of vegetation along pest and monitoring lines to enable access for people to service the bait stations and monitoring tunnels. Hand tools will mostly be used to trim

vegetation. A chainsaw may be used to trim dense patches of kiekie or supplejack and may only be operated by persons with chainsaw use qualification.

6) Baiting of bait stations with Pest-Off animal toxin supplied by the Auckland Regional Council following the Ark in the Park operational baiting procedures.

Note: Installation of kill traps for stoats and cats will also be added to the new site by the Ark in the Park organisation as part of achieving integrated pest control.

Other Consents/Permits Required:

Approval is required from Watercare Services to establish pest lines, bait stations, rodent tracking tunnels, and lay Pest-Off toxin within the Waitakere Catchment area.
This has been granted.

Regional Park Use Conditions:

1. A health and safety plan needs to be provided prior to working at the site to the Senior Ranger - Conservation (Western Sector – contact Alison Davis 098170084). You will be notified of site hazards prior to starting work.
   - The notification procedure used by the Ark in the Park project must be followed when working on the Park. This is to cover notification to the Cascade Depot, and daily check-in and check-out procedures. In addition the Auckland Regional Council can provide support by contacting the Arataki Visitor Centre ph.098170077during work hours (9.00am-5.00pm, seven days/week) or after hours the ARC Contact Centre 093662000 who will page the duty supervisor for the Waitakere Ranges Regional Park.
2. Please ensure that you are familiar with the park bylaws and your responsibilities while working in the park. These include protecting the natural character, historic, archaeological and biological features of the park, removing/recycling all litter and debris generated by your activities, and not interfering with public access and enjoyment of the park.
3. No trees, shrubs or plants (including seedlings) are to be permanently marked, damaged or taken as part of this permit, unless permitted by this consent.
4. No animals on the Park are to be handled or taken unless allowed by this consent. Where protected wildlife under the Wildlife Act is to be handled a permit is also required from the Department of Conservation.
5. All tools, equipment and clothing must be clean and uncontaminated by dirt, animal or plant material prior to entering the site and if it has come into contact with wildlife, sterilised with anti viral solutions.
6. The consent holder must comply with the attached procedures to halt the spread of Kauri dieback disease. Failure to comply with these procedures may result in your consent being revoked.
7. The consent holder shall not erect or bring onto the park any structure, install any facility, or alter the sites in any way unless permitted by this consent or with the prior written consent of the Senior Ranger Conservation.
8. Tools or equipment left on the park overnight are at your own risk. During the day tools and equipment not in use are to be placed well out of view from public walking tracks and recreation areas.
9. Access is by foot only or on approved vehicle access tracks.
10. Bait stations, rodent tracking tunnels and markers installed as part of this research will be the property of the Ark in the Park organisation.
11. Upon completion of the research, the consent holder shall forward either a hard or electronic copy of the research findings, reports and publications to the Senior Ranger – Conservation, Western Sector (Alison Davis, Arataki Visitor Centre, PO Box 60-228, Titirangi, Waitakere City).
12. This consent is valid from 20 October 2009 to the 31 December 2010, Should you require it, you will need to apply for a renewal one month prior to the expiry of this consent. Note that this consent can be revoked, with immediate effect, either verbally or in writing, should any ARC representative believe this study is adversely affecting the values of the Regional Park.
13. The fee for this application has been waived as this is an ARC supported project.

Please sign two copies of this document indicating agreement to the above conditions and forward one copy, to this office, before starting research on the Park. The second copy is for your records.

Return Address:
Arataki Visitor Centre
PO Box 60-228,
Titirangi, Waitakere City

Yours sincerely
Alison Davis
Senior Ranger, Conservation
Western Sector
Auckland Regional Council
Ph. 098170084

Applicant
Name: Andy Warneford

Delegation (Principal Ranger, Western Sector Parks, Auckland Regional Council)
Name: Stephen Bell

PROCEDURES FOR KAURI DIEBACK DISEASE– RESEARCHERS/PLANT COLLECTORS

A requirement to comply with these Procedures will be a condition of all researchers and plant collectors with a discretionary use consent operating in the Waitakere Ranges Regional Park.

The following procedure will be followed:

1. Researchers or plant collectors will **check-in and check-out** in person, or by phone, fax or email each day they work on the Park (Contact Arataki VC ph.098170077, fax 098175656, or email arataki.centre@arc.govt.nz).

2. All **footwear, tools and machinery to be soil-free** when working on the Park on each occasion. It is recommended that cleaning occurs at the beginning and end of each day.

3. **Wheeled or tracked machinery may be inspected for its cleanliness by Park staff** prior to its use on the Park, and when leaving the Park. Generally the machinery will be required to remain on-site for the duration of the job.

4. Portable phytosanitary packs must be carried when working on the Park.
   Carry a **phytosanitary car-kit** in all vehicles to use before entering tracks and leaving tracks
   Carry a **phytosanitary back-pack** kit when working off track – use immediately before leaving track and again before re-entering track, and after leaving a disease zone.
   Phytosanitary supplies may be obtained from the Arataki Depot (ph.098170099)

5. **Cleaning facilities including outdoor wash-tubs**, brushes, and water are also available at each Depot (Arataki ph.8170099, Huia ph.8118897, Piha ph.8128860 and Cascades ph.8108133) to clean footwear, tools and equipment at the beginning and end of each day

Park Staff will be monitoring compliance with these Procedures
As information on the distribution of the disease becomes available stricter procedures and use of fungicides may be required.
Diseased areas may be closed in the future.

Other Actions

- Keep to formed tracks as much as possible
- Avoid working off-track in wet conditions
- Be particularly vigilant working around Kauri stands and trees, and sites where the disease is known to be present
- Pass the key message of keeping footwear soil-free to all Park users

Appendix II Brodificoum safety data sheet

SAFETY DATA SHEET

Brodifacoum Baits 20ppm Issued September 2006 Page ***1 of 4***
Animal Control Products Ltd
1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION
Product Name: (a) PESTOFF RODENT BAIT
(b) PESTOFF RODENT BAIT 20R
(c) PESTOFF RODENT BLOCKS
(d) PESTOFF BRODIFACOUM POSSUM BAIT
(e) PESTOFF WAXED POSSUM BAIT
Synonyms: (a) – (c) Pestoff rodenticide
(d) – (e) Pestoff possum bait
Supplier 1: Animal Control Products Ltd
Street Address: 408 Heads Road
Wanganui
New Zealand
Telephone: 64 (0) 6 344 5302
Facsimile: 64 (0) 6 344 2260
Supplier 2: Animal Control Products Ltd.
Street Address: 10 Hayes Street
Waimate
New Zealand
Telephone: 64 (0) 3 689 8367
Facsimile: 64 (0) 3 689 8804
After Hours Numbers:
0274 798 318 or
0274 798 319
Emergency Telephone Number
National Poisons Centre:
0800 764 766
2. COMPOSITION / INFORMATION ON INGREDIENTS
Product Name:
(a) PESTOFF RODENT BAIT
(b) PESTOFF RODENT BAIT 20R
(c) PESTOFF RODENT BLOCKS
(d) PESTOFF BRODIFACOUM POSSUM BAIT
(e) PESTOFF WAXED POSSUM BAIT
Synonyms: (a) – (c) Pestoff rodenticide
(d) – (e) Pestoff possum bait
Active Ingredient: Brodifacoum @ 0.002% w/w
Other Ingredients: Cereals, sugars, waxes and binders.
Molecular Weight of Active: 523.4
Molecular Formula of Active: $C_{31}H_{23}O_3Br$
Recommended Use: Cereal based baits for rodent or possum control.
Appearance: Extruded solid cereal blocks or baits dyed green or blue
Brodifacoum Baits 20ppm Issued September 2006 Page ***2 of 4***
3. HAZARD IDENTIFICATION
STATEMENT OF HAZARDOUS NATURE
HAZARD CLASSES (HSNO): 6.9B, 9.1D
HAZARD IDENTIFIERS: Priority Identifiers – Harmful, Ecotoxic, Keep out of reach of children.
Secondary Identifiers - Harmful substance.
Repeated oral exposure may cause toxin to

accumulate in internal organs and may affect the
clotting ability of the blood.

DANGEROUS GOODS CLASS:

Not classified Dangerous Goods as toxicity falls
below Packing Group III threshold.

SYMPTOMS OF POISONING: No symptoms may be apparent for several days if poisoning has occurred. Can kill if swallowed in large quantities. The active constituent (Brodifacoum) is an anticoagulant
chemical, which if taken by humans, domestic animals or pets, will reduce the clotting power of the blood. Nausea and vomiting may occur soon after ingestion, however in some cases effects from exposure may be delayed for several days or may not be evident unless checked by a physician. Typical overt symptoms of poisoning include bleeding gums, increased tendency to bruising, blood in urine and faeces and excessive bleeding from minor cuts. Haemorrhagic shock, coma and death may follow in cases of severe poisoning.

4. FIRST AID MEASURES

Ingestion: In the event of ingestion, do not induce vomiting. Consult a physician and provide an estimation of the amount of product ingested. In the case of very small amounts of product (< 10 grams) being taken, no symptoms may develop but larger amounts may affect blood clotting times. A physician can assess this and provide Vitamin K_1 therapy as necessary.

Eye Contact: Wash eyes with water.

Skin Contact: Wash exposed area with soap and water.

Contaminated

Clothing: Remove contaminated clothing and wash before re-use. Wear gloves and overalls when handling baits. Do not eat, drink or smoke. Clothing and gloves must be decontaminated by washing in hot soapy water.

As symptoms of poisoning may not appear for several days, always consult a doctor where poisoning is suspected.

5. FIRE FIGHTING MEASURES

Low flammability risk. Baits have no toxic emissions as either vapours, gases or odours. The primary hazard is by ingestion**.**

6. ACCIDENTAL RELEASE MEASURES

In the event of a spill, isolate the spill area and take all practicable steps to manage any harmful effects of a spillage including preventing baits from entering streams or waterways. Scoop spilled baits into secure containers. Recover any undamaged bait for later use by placing in appropriately labelled containers and dispose of spoiled bait as directed in the disposal section below. Use a broom to collect fine material and wash down the spill area with copious water only after all spilled bait has been removed.

7. HANDLING AND STORAGE

*Brodifacoum Baits 20ppm Issued September 2006 Page **3 of 4***

Wear impervious gloves when handling baits or open containers. Do not eat, drink or smoke when using the product or handling open containers. Remove protective clothing and wash hands and exposed skin thoroughly before meals and after any contact.

Store in original container, tightly closed and away from feed or foodstuffs. Keep out of reach of children and domestic animals.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Limits: Not applicable (not assigned).

Engineering Measures: Decontaminants are water and microbial decomposition.

Personal Protection Equipment: Operators using or handling the product in open containers must wear gloves and overalls. When working around aircraft, wear a dust mask to prevent inhalation of airborne particles.

9. PHYSICAL AND CHEMICAL PROPERTIES

Form / Colour / Odour: Pellet and block baits have a solid cylindrical form, are dyed blue or green and may have an odour of cinnamon, fruit flavouring, or chocolate.

Solubility of technical grade Brodifacoum Water at pH 5.2 = 0.00
7.4 = 0.38
9.3 = 1.00
Toluene 0.72
Acetone 2.30
Methanol 0.27

10. STABILITY AND REACTIVITY

Brodifacoum cereal baits are stable and non-reactive under normal storage and use conditions.

11. TOXICOLOGICAL INFORMATION

The baits present a very low hazard to operators unless taken orally.

TOXICITY DATA FOR THE ACTIVE INGREDIENT - VARIOUS SPECIES*
White laboratory rat (oral) LD_{50} 0.26 mg//kg B/W
Brush-tailed possum (oral) LD_{50} 0.8 mg/kg B/W
Dog (oral) LD_{50} 3.56 mg/kg B/W
Cat (oral) LD_{50} 25.0 mg/kg B/W
Mouse (oral) LD_{50} 0.4 mg/kg B/W

12. ECOLOGICAL INFORMATION

Use the pellets only for the purpose indicated and in the manner prescribed by the product label. Brodifacoum may persist for many months in the fatty tissue, liver and kidneys of sub-lethally poisoned animals. Mortally poisoned animals may present a secondary poisoning risk to carnivorous birds and mammals and in addition a tertiary poisoning risk where for example feral pigs eat poisoned possums and are subsequently taken and eaten by pig hunters. Take steps to mitigate any potential non-target exposure by wildlife, domestic animals or humans. Studies have shown that Brodifacoum concentrations will decline within rotting carcasses.
Improper disposal of excess pesticide is unlawful. If wastes can not be disposed of according to label instructions, contact local Regional Council or a hazardous waste advisor for guidance.

13. DISPOSAL CONSIDERATIONS

Product which is damaged or spoiled should be disposed of by burying with other organic material on the active tip face of an appropriately managed landfill or buried within the biologically active layer of soil elsewhere within a secure area. Ensure that a good covering of earth is applied over the bait immediately to prevent access by scavenging birds. Alternatively, burn unwanted bait material in a suitably constructed and appropriately located incinerator and bury any residues as above. The emissions from burning bait are likely to cause nausea, so ensure wind direction is favourable before burning. Treating the baits through a sewage oxidation facility or other chemical treatment facility is also an acceptable means of disposing of unwanted bait material. Burn empty bags or bury at a landfill. Do not use the empty container for any other purpose.

14. TRANSPORT INFORMATION

Proper Shipping Name: Not Applicable – Not classified as Dangerous Goods due to low toxicity
U.N. NO: Not Applicable
Class: Not Applicable
Packing Group: Below PG III threshold for Dangerous Goods
Maximum transport quantity when for use as tools of trade = No limits

15. REGULATORY INFORMATION

Registered Pesticides: V004991(Pestoff Brodifacoum Possum Bait), V005136 (Pestoff Waxed Possum Bait), V005137 (Pestoff Rodent Bait), V009014 (Pestoff Rodent bait 20R), V005099 (Pestoff Rodent Blocks).

16. OTHER INFORMATION

Do not use poisoned or contaminated animals for food or feed.
This product is toxic to most wildlife. Birds and mammals feeding on carcasses of contaminated animals may be killed. Take measures to minimise the chance of baits entering any body of water. Apply the product only as specified by its label directions.
Where practicable, the exposed bodies of all poisoned animals should be collected and destroyed by complete burning or deep burial at a landfill approved for hazardous wastes.
CONSULT NEAREST POISON CONTROL CENTER FOR CURRENT INFORMATION.
All information contained in this Data Sheet is as accurate and up-to-date as possible. Since Animal Control Products Ltd. cannot anticipate or control the conditions under which this information may be used, each user should review the information in the specific context of the intended application.

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