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THE BEHAVIOURAL RESPONSES OF STOATS (*Mustela erminea*) TO TRAPPING TUNNELS.

A thesis

submitted in partial fulfilment

of the requirements for the Degree of

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The behavioural responses of stoats (*Mustela erminea*) to trapping tunnels.

by Samantha Brown

Stoats (*Mustela erminea,* Linnaeus 1758) are a major conservation pest in New Zealand, and they are presently the focus of much research to improve the efficacy of their control (Department of Conservation, 2000). Tunnels are used in almost all aspects of monitoring and control associated with stoats, yet few studies have investigated the influence of tunnel design on stoats' behavioural responses to them, or the effect on capture rate (Dilks *et al.*, 1996; Maxwell *et al.*, 1997; Short and Reynolds, 2000). This thesis describes pen and field research, which examines the influence of several tunnel design variables on stoat entry behaviour. This information will be used to assist in designing a trapping tunnel for a new repeat-kill, permanent-set kill trap for sustained control of stoats in indigenous forest, currently being developed at Lincoln University.

The investigative behaviours of captive stoats were videoed in large outdoor pens. I investigated the effects of diameter (50, 100 and 150 mm), length (400, 600 and 800 mm) and end type (open, closed and mesh) on stoat entry behaviour into a variety of PVC pipe tunnel types. Three hair collection methods, suitable for monitoring stoats, were also trialed both in the pens and in the field. Initial and repeat entry behaviour was observed as well as general investigative behaviour toward the tunnels.

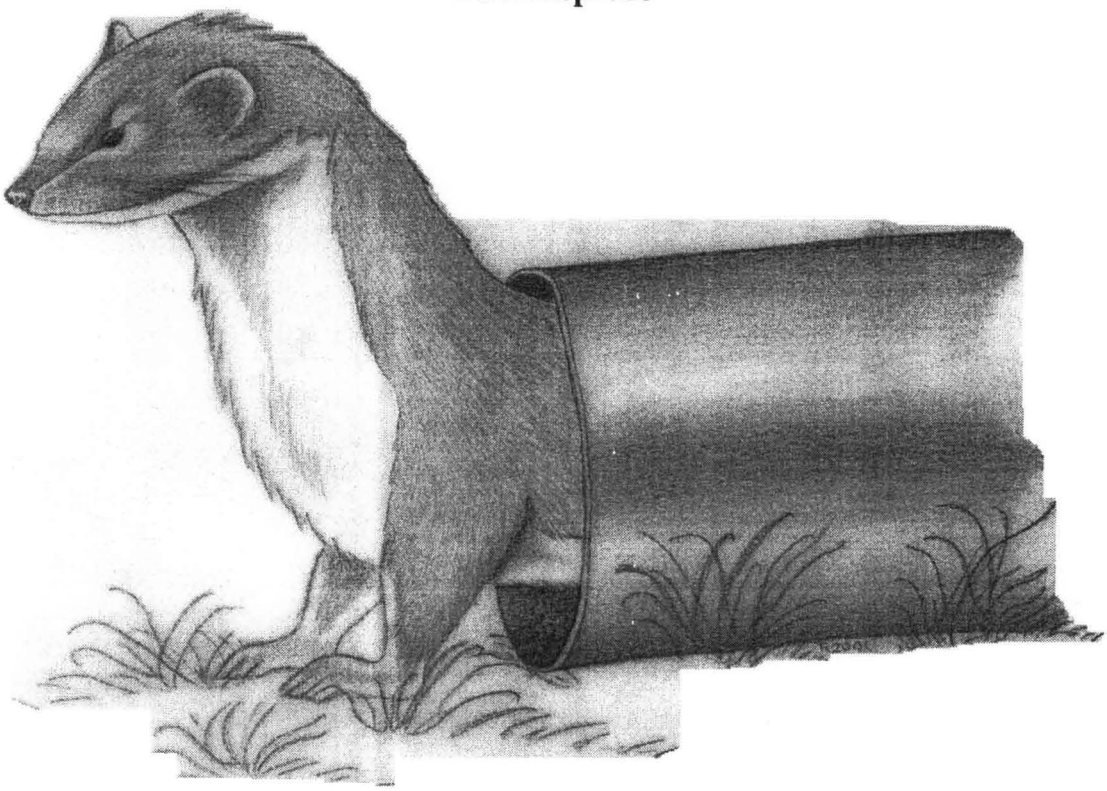
Diameter does affect repeat entry type and frequency in closed ended tunnels, however, the comparison of tunnel diameters in open-ended tunnels demonstrated that diameter alone may have a minor effect on stoat entry behaviour. Diameter did not effect initial entry behaviour into any of the tunnel types and had no influence on the depth to which stoats entered the tunnels. Longer tunnels may encourage more body entries into

smaller (50 mm) diameter tunnels. However, stoats were reluctant to proceed to the end of the tunnels of any length. End type affects both initial and repeat entry behaviour in all tunnel types, although it is more apparent in tunnels with a smaller diameter. Removal of the end cap resulted in significant changes in repeat entry behaviour into the 50 and 100 mm tunnels. Addition of a mesh end cap appeared to discourage stoats from entering 50 mm tunnels. During field trials, stoats were detected in both open and closed-ended tunnels, but more frequently in closed-ended tunnels. The hair collection methods successfully collected adequate hair samples in the pen trials but did not perform as well in the field.

Tunnel design does influence stoat entry behaviour and all new tunnel designs should undergo testing prior to use in the field. With no difference in initial entry behaviour, a small (50mm) closed-ended tunnel is likely to reduce non-target entries and position the stoat correctly for a humane kill with the new kill device.

Keywords: Stoat; *Mustela erminea*; tunnel design; trapping, stoat control, diameter; length; end type; hair trap; monitoring; exploratory behaviour; video observations; captivity.

Frontispiece



Stoat (*Mustela erminea*) exiting an open-ended 50 mm tunnel. (Drawings: Ruth Guthrie)

Stoat investigating a 50 mm tunnel .

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CHAPTER ONE

General Introduction

Stoats (*Mustela erminea,* Linnaeus 1758) are a major conservation pest and their control is the focus of much research at present (Department of Conservation, 2000). This thesis describes pen and field research aimed at developing a tunnel suitable for use with a recently developed stoat kill trap. The work was done as a Master of Science in the Ecology and Entomology group at Lincoln University in collaboration with the Environmental Management and Design division and Landcare Research. It was funded by Lincoln University and a joint Landcare Research / Environmental Management and Design division scholarship.

This thesis is structured into seven chapters. Chapter one is divided into two parts, the first outlines aspects of stoat ecology relevant to their control in New Zealand, while the second introduces the current control methods employed against them and the importance of tunnel design to control. Chapter two outlines the general methodology applicable to all four pen trials. Chapter three examines the effects of tunnel diameter and end type on stoat entry behaviour. Chapter four examines the effects of tunnel length on stoat entry behaviour. Chapter five describes the development of several new hair collection methods. Chapter six outlines the results of the field trial, which tested the tunnel design and hair collection methods, developed in pen trials. Chapter seven is a general discussion, which outlines the key results of the thesis and the implications of these results to stoat management in New Zealand.

1.1 Ecology

1.1.1 Introduction to New Zealand

Stoats, from the family Mustelidae, are small mammalian carnivores, which are distributed throughout the Northern Hemisphere (King, 1989a). They were first introduced into New

Zealand from Britain in 1884 as a form of biological control for rabbits (*Oryctolagus cuniculus cuniculus*) despite opposition from ornithologists (King, 1990; Basse *et al.*, 1999). Rabbits had become a major agricultural pest and it was believed by some people that introducing their natural enemies, stoats, ferrets (*Mustela putorius furo*) and weasels (*Mustela nivalis*), would alleviate the problem (Murphy, 1992). It became evident soon after their release that these mustelid species were not going to provide the control needed to end the rabbit problem (King and Moors, 1979). Stoats in particular invaded the forests and found easy prey among New Zealand's many species of ground nesting birds (King, 1990). As stoats are adept climbers, tree-nesting species also suffered (King, 1990). Introductions ceased in 1902, but by this time mustelids had spread into most areas of the country. It was not until 1936 that all legal protection for mustelids was removed and they became recognised as pests (King, 1990).

Stoats now occur in a wide variety of habitats throughout both the North and South Islands in New Zealand. They are found in open pasture and dense forest, from sea level to above the tree line (King, 1990). They are the most common carnivores in New Zealand forests (Wilson *et al.*, 1998). However they are absent from most offshore islands, except those within their swimming range where they have become self introduced (Taylor and Tilley, 1984).

1.1.2 Stoats as a conservation pest

New Zealand bird species have evolved strategies to contend with avian predators but have no innate defence mechanism against mammalian predators (Holdaway, 1989; Bunin and Jamieson, 1996; O'Donnell, 1996b). The Takahe (*Porphyrio mantelli*) suffers stoat predation on eggs, chicks and adults. In contrast Pukeko (*Porphyrio porphyrio*), a self-introduced species that evolved in the presence of predatory mammals, will defend their nests against stoats (Bunin and Jamieson, 1996). Although stoats were not part of the historical extinctions that followed the arrival of both Polynesian and European settlers,

they now threaten those native species that remain and are frequently held responsible for the decline of a number of native bird species (King and Moody, 1982a; King, 1984; Flannery, 1994). The Department of Conservation (DOC) is responsible for stoat control in areas where they are considered to threaten the survival of native bird species.

At present, predation is a major threat to the survival of kokako (*Callaeas cinerea wilsoni*), black stilt (*Himantopus novaezelandiae)*, kakapo (*Strigops habroptilus*), yellow-eyed penguin (hoiho) (*Megadyptes antipodes*), mohua (yellowhead) (*Mohoua ochrocephala*), North Island brown kiwi (*Apteryx australis mantelli*), great spotted kiwi (*Apteryx owenii*) and kaka (*Nestor meridioalis*) (Alterio *et al.*, 1998; Basse *et al.*, 1999). Stoats have been identified as an important predator in most of these cases. Individual stoats may have a severe impact at a local level. Excavations of two dens used by one female stoat and her litter revealed the remains of at least eleven northern New Zealand dotterels (*Charadrius obscurus aquilonius*), as well as egg fragments and chick remains (Dowding and Murphy, 1996).

For northern brown and great spotted kiwi, predators were responsible for an estimated 10% of egg losses, 8% of nestling mortality and between 45% and 60% of fledging mortality, with stoats being identified as the major predator in most cases (McLennan *et al.*, 1996). The predation of nesting female kaka by mammalian predators, particularly stoats, has led to a skewed sex ratio toward males, which affects the species' long-term viability (Wilson *et al.*, 1998).

Mohua are now absent from over 75% of their former range, this is partly due to habitat destruction but in some cases they have also declined in unmodified areas (O'Donnell, 1996c). These declines have been attributed to predation. Mohua are especially vulnerable to predation by stoats as their breeding season coincides with peak stoat density, and they spend an extended time on the nest and nest in holes (O'Donnell *et al.*, 1992). Six mohua population crashes have coincided with stoat irruptions following mast-seeding events. In non-mast years stoat predation has little affect on productivity, but

during stoat eruptions 67% of nests and 50% of nesting females have been destroyed (Elliott, 1996). Predator trapping has been shown to significantly increase mohua breeding success and female survival during a stoat irruption year (O'Donnell *et al.*, 1992).

Presently most stoat control efforts are concentrated during the breeding seasons of endangered bird species such as the kaka and mohua, as it is during this period that the birds are most vulnerable to predation, either as nestlings or nesting females (Wilson *et al.*, 1998). Many species' breeding seasons also coincide with the stoat breeding season when the female stoat has much higher food requirements and there is an influx of independent juvenile stoats (King, 1984). For most bird species this period is relatively short, three to four months at most, however other species such as the kiwi, where juvenile birds are most susceptible to predation, are at risk for a much longer period. These species require protection from predation for a sustained period. Ideally stoat densities need to remain at or under 2 stoats per km^2 to ensure the survival of most endangered bird species (Basse *et al.*, 1999).

1.1.3 Morphology

Stoats have the typical long thin mustelid body shape and are particularly flexible (King, 1990). Their body shape allows access to most prey refuges, and they are able to move within the tight confines of their preys' tunnels. Simms (1979) suggests that the body size of stoats has evolved to optimise their ability to hunt small, tunnel - dwelling mammals. Because of mammalian muscle construction stoats are stronger, for their size, than most larger predators; in effect this allows them to capture and carry prey larger than themselves (King, 1989b). They have both day and night vision and an acute sense of smell and hearing. Stoats can climb over 15 m high and swim in both fresh and salt water for up to 1200m (Taylor and Tilley, 1984; King, 1990), A. Win pers. obs.). Their morphology and sensory perception make them extremely effective hunters of most available prey species.

New Zealand stoats are large by comparison to most populations in other countries (New Zealand males 285 - 356g, European males 208 - 283g) (King, 1983b; King, 1990). Within New Zealand body size varies considerably depending on habitat type (King and Moody, 1982c). Studies by King and Moody (1982c) revealed there is almost as much geographic variation in size between male stoats in New Zealand as there is across all of continental Europe. Therefore, tunnels used as part of a control or monitoring operation must be able to accommodate the largest males so no individuals are accidentally excluded.

Stoats display obvious sexual dimorphism; males are on average up to a third larger than females and over 50% heavier (Average male weight 324g, Average female weight 207g) (King, 1990). The larger size in males is attributed to the pressure to outcompete other males for access to females (King, 1989b). Females maximise their foraging efficiency (especially while feeding young) by remaining small enough to access prey refuges (Simms, 1979; King, 1989b). This difference in size between the sexes has an important influence on several aspects of their ecology including prey selection, foraging strategy and territory size. These differences need to be considered during trap design as they may influence the likelihood of capture, which would impact on the success of a trapping study.

1.1.4 Reproduction and mortality

Stoats are able to increase their population substantially in response to increases in food availability (King, 1990). Stoats produce one litter a year and development is suspended for nine to ten months after fertilisation (McDonald and Lariviere, 2000). Changes in day length trigger implantation, but the number of young produced is dependent on food availability at this time as blastocysts can be reabsorbed (Erlinge, 1981; King, 1990). If conditions are favourable, up to ten young are produced (Sleeman, 1989; King, 1990). This

population growth can result in increased bird predation and requires increased control efforts to effectively protect vulnerable species.

High male mortality will not have any affect on population growth for the following year, because females are already pregnant with the following years litter (King and Moors, 1979)(King, 1983b). Stoats have a naturally high mortality rate, which is usually the result of starvation (McDonald and Lariviere, 2000). A study conducted in Pureora Forest Park (North Island, New Zealand) estimated that first year mortality was about 76% (King *et al.*, 1996a). Consequently, most control operations simply remove animals that would soon perish anyway (King, 1984). It is very difficult for control operations to impose additional mortality on to a population. Reducing breeding success by increasing female mortality and decreasing litter sizes are the keys for longer-term stoat population reduction (McDonald and Lariviere, 2000).

1.1.5 Diet

Prey density and distribution is one of the key parameters controlling stoat populations (King, 1989a). Diet studies conducted in New Zealand have found that stoat's diets are mainly comprised of birds, mice, lagomorphs, rats, possums and insects (King and Moody, 1982b; Murphy and Dowding, 1994; King *et al.*, 1996a). Lizards, freshwater crayfish, rubbish and carrion also form a small part of the diet in some areas (King and Moody, 1982b; King *et al.*, 1996b). Bird remains were found in over 40% of stoat guts, mice in 21.9% and weta remains in 34.6% (King and Moody, 1982b).

The proportion of each prey type eaten varies widely between different habitat types, seasons and sexes. Much of this variation is due to changes in prey availability; i.e. mice make up a greater proportion of the diet in autumn because they are more abundant at this time, especially during beech mast seeding years (King, 1983a; Murphy and Dowding, 1995). However they may be absent in the diet following mast seeding years when the mice population crashes (Murphy and Dowding, 1994).

In New Zealand, the prey species available to stoats are generally larger and less varied than the types of prey normally present overseas (King and Moody, 1982a). Females tend to take smaller prey items than males, although both sexes have been observed to take prey items much larger than themselves (King and Moody, 1982b). The prevalence of larger prey items such as possums in the diet of male stoats may be due to males scavenging from road kills more frequently than females (Murphy and Dowding, 1994). Bait preference trials indicate that females may prefer different bait types, which could be a reflection of differences in diet (Murphy *et al.*, 1992). These differences in prey preferences may impact on the success of bait types used in control operations.

Stoats evolved in areas with large fluctuations in prey availability, therefore will often kill regardless of their level of hunger, and store the excess (King, 1990). This is a more efficient strategy than storing excess energy as body fat, because any increase in size would restrict the proportion of tunnel dwelling prey available (Simms, 1979). Because of their high metabolic requirements, 'easy meals' from bait stations or traps become more appealing as food resources decline.

1.1.6 Foraging behaviour and activity

Stoats are bold and active hunters that will range widely in search of prey. They are naturally curious animals and will investigate most hollows and openings in search of a potential meal (King, 1973a; King, 1983b). They are small enough to enter most burrows and flexible enough to turn round in them (King, 1990). In North America and Europe, they excel in hunting small burrowing mammals such as voles and rodents (Simms, 1979). Hunting is normally focused on areas of scrub or other disturbed habitat that prey species favour (Vaisfield, 1972). In snow covered areas stoats will hunt prey in subnivian (under snow) tunnels (Simms, 1979). When hunting, stoats normally take the most direct route to a potential area, but once in the hunting area their trails become very tortuous as they

throughly investigate the area (Vaisfield, 1972). Control operations attempt to exploit stoats' exhaustive foraging behaviour and natural curiosity (King and Edgar, 1977).

Stoats are very mobile animals and will range widely, males moving up to 4 km in 5 hours (Murphy and Dowding, 1994). Dispersing juveniles can travel extensive distances, for example, one individual travelled up to 65km in four weeks (Murphy and Dowding, 1995). This often results in rapid reinvasion of an area following a control operation (Murphy and Dowding, 1994). Activity varies with season, resource availability and reproductive condition (Samson and Raymond, 1995; Alterio and Moller, 1997). Males range widely in their search for mates, while females often reduce their activity while raising a litter (Erlinge and Sandell, 1986). This means that variation in capture success may be a reflection of changes in activity rather than stoat density.

1.1.7 Home range, and habitat

Knowledge of home ranges is important for determining trap spacing. Differences in home range size have been touted as one explanation for differences in capture rate between males and females (King, 1975a; Buskirk and Lindstedt, 1989). The average size of stoat home ranges in beech forest varies between mast and non-mast years (Murphy and Dowding, 1994; Murphy and Dowding, 1995). In most years females have an average range of 124 ha and males have a range of 206 ha (Murphy and Dowding, 1994). The size of these home ranges contracts during periods of high density, such as a mast year, to 63 ha for females and 93 ha for males (Murphy and Dowding, 1995). There is little overlap between individuals of the same sex, although a male's territory will often overlap with several females (Murphy and Dowding, 1994).

Each individual has one to three regular dens as well as several casual ones (Murphy and Dowding, 1995); these are often taken over from prey. In New Zealand the most common den sites are in old rabbit burrows or rat nests (Murphy and Dowding, 1995).

In both New Zealand, and other countries stoat distribution is primarily influenced by the distribution of prey and suitable habitat (Doyle, 1990). The size of the animals' home range is determined by resource availability in the area (Murphy and Dowding, 1995). They prefer to stick to cover in open areas and will concentrate on sites likely to harbour prey species such as forest edges, riparian zones and hedgerows (King, 1983b; Murphy and Dowding, 1994). In exotic plantations the area of highest stoat density coincided with areas of high rat density, which diet studies identified as an important prey item (King *et al.*, 1996b). Home ranges are in effect a series of patches of high resource value; therefore stoats do not spend an equal amount of time in each area. Identifying these areas may assist in trap placement, as unsuccessful traps are often sited in infrequently visited areas (King, 1973b).

1.1.8 Social communication

Stoats are solitary animals during most of the year, with the exception of mating and while females are raising their litters. Females are dominant over males during this period but for the rest of the year the male is the dominant sex (Sleeman, 1989). Aggressive interactions between stoats are an infrequent occurrence and mutual avoidance or retreat are the more common tactics employed to maintain social structures (King, 1991). Because of this, scent marking plays an important role in stoat communication.

Stoats use scent glands located in the anal region and the skin as a communication tool to mark their territories and also in encounters with other stoats (Sleeman, 1989). Anal drags are used to mark territories and can be renewed while hunting, while body rubbing occurs during agnostic encounters and is part of a threat display (Erlinge *et al.*, 1982). As the scents are individually distinct it is likely that they convey information on the individuals' social status and identity. Dominant stoats scent mark more frequently and subordinate stoats will often react fearfully when they come into contact with strange scent

markings (Sleeman, 1989; King, 1990). Stoats may deposit scats in a highly visible place to signal their possession of a territory (King, 1990).

Scent is important to stoats for within species communication so human scent on traps and tunnels may affect stoat reaction to them. The effect of human smell on stoat behaviour has been widely discussed but very little work has actually been done on establishing what affect it may have. Some trapping operations go to a lot of effort to reduce human scent on the traps (Crouchley, 1994), but many others do not. Anecdotal evidence suggests that stoats may avoid traps that have a human scent, so an effort is now made to reduce human scent on traps by using gloves and boiling traps (Warburton, 1997). The olfactory properties of different baits may be important in their success at attracting animals (Spurr, 1999). The scent of dominant individuals can cause avoidance of nest sites in subordinate stoats (Erlinge *et al.*, 1982). Lures relying on anal gland excretions need to take this into account as they could actually repel subordinate individuals.

1.2 Control and Management

Tunnels are fundamental to current control and monitoring methods. All kill traps used for stoat control are housed in tunnels and poisoned bait stations rely on tunnels to exclude non-target species. Tracking tunnels are the most commonly used non-invasive sampling method. In addition, all mark-recapture and live trapping studies use live capture traps. Despite our complete reliance on tunnels for all aspects of stoat research and control, there has been very little research on any aspects of their design and the possible effect it may have on the likelihood of capture or detection of stoats.

1.2.1 Barriers to control

Several aspects of stoat biology, as outlined above, make them particularly resistant to control. Firstly stoats have the capacity to rapidly increase the population density in

response to increased food availability (King, 1989a). Females become pregnant soon after giving birth; so control operations that kill a high proportion of the available males have no effect on the populations' reproductive potential (McDonald and Lariviere, 2000). Stoats have a naturally high mortality rate, this means that the higher kill rates that are usually achieved in summer and autumn have little affect on next year's population as it is simply removing animals that would perish soon anyway (King, 1984). Not all individuals are equally trappable and females are generally more difficult to trap (King, 1994a). They are able to reinvade a cleared area rapidly and even if extensive areas are controlled, stoats are adaptable enough that they will always remain in some areas (King, 1984). Finally, they are solitary animals, sparsely spread over large areas.

Although these life history tactics make stoats resistant to control they are not entirely unsusceptible. Because they hunt small rodents (and in New Zealand hole nesting birds), stoats will investigate any possible prey refuge and in addition they are naturally curious animals. Trap based control operations attempt to exploit this quality (King and Edgar, 1977). Reproductive success is heavily influenced by prey availability so there has been speculation that reducing prey density prior to the period when blastocysts are implanted may stop the numerical response to increased prey density (McDonald and Lariviere, 2000).

Mustelids have been controlled in Britain since the 19th century, yet this has had little affect on the viability of the stoat population. The introduction of myxomatosis was more effective in reducing the stoat population than over a century of trapping (King, 1989a). It is generally accepted in New Zealand that stoats can be controlled temporarily in small areas, but current methods will never be effective in eradicating stoats. Control is most effective when practised intensively over short periods of time when species in need of protection are at their most vulnerable (i.e. during breeding) (King, 1984).

1.2.2 Mast seeding

The link between beech mast seeding, rodents and stoats has been studied at length over the last 20 years (King, 1983a; Murphy and Dowding, 1995). Stoat numbers increase significantly in the period following a mast-seeding event in response to increased rodent density (King, 1983a). An increase in bird and invertebrate densities may also contribute to the rise in the stoat population (Murphy and Dowding, 1995). Stoat density per km^2 can increase five fold in mast years (Basse *et al.*, 1999). The fluctuations in density require different trapping responses to maximise capture efficiency for trapper effort.

The increase in stoat density associated with a mast seeding event results in the most serious damage to endangered bird populations. Predation by stoats is often a negligible factor in population mortality, however in mast years total predation levels on birds' increase, although the proportion of birds in individual stoat diets remains similar to premast levels (King, 1983a; Murphy and Dowding, 1995). This can result in massive population crashes of certain species (e.g. Mohua (Dilks, 1997)). Increased control efforts are necessary during this period to protect vulnerable species. The increase in rodent densities may influence trappability of some animals as food is not limited, so bait may not be such an effective lure (Alterio *et al.*, 1999).

1.2.3 Monitoring

Monitoring the species you are trying to protect is the best way of assessing the success of any control operation (King, 1994a). In addition, to determine both the necessity and success of any control operation, a method of monitoring the current stoat population density, and any changes in that density following the control operation is needed (Murphy *et al.*, 2000). Traditionally, trapping rates and tracking tunnels have been used to gauge the necessity of mustelid control operations or to monitor reinvasion rates to an area, and while this is a reliable index of ferret abundance (Cross *et al.*, 1998) it has not been quantified for stoats (Murphy *et al.*, 2000). However as a small, nocturnal, fast moving species direct

observation is next to impossible, so the indirect information provided by tracking tunnels and trapping operations is vital (King and Edgar, 1977). Stoats are more susceptible to trapping in times of low food abundance, especially when baited traps are used (Alterio *et al.*, 1999). This may mean that changes in population size are underestimated as proportionally fewer stoats are caught in high population years, when food is more readily available (Alterio *et al.*, 1999).

Alternative monitoring methods, such as hair trapping have received little attention in New Zealand. Landcare Research is now trying to develop hair traps for stoats and possums to study population dynamics, as a non-invasive alternative to current monitoring techniques (Warburton *et al.*, 2000). Hair trapping has been successfully used as a monitoring tool for a number of species overseas and is becoming more widely used as DNA analysis becomes more advanced (Sloane *et al.*, 2000). There are a variety of methods available for hair collection and in Australia hair tubes containing sticky wafers are frequently employed to sample small mammal species present in an area (Suckling, 1978; Scotts and Craig, 1988; Valderrama *et al.*, 1999). In addition to providing information on the presence of a species in an area, DNA analysis of hair follicles can identify individual animals. Therefore, hair sampling could be used to track the movements of individuals or supply information on population trends within an area (Valderrama *et al.*, 1999; Sloane *et al.*, 2000; Blair, 2001).

1.2.4 Poisons

Poisoning has two main advantages over trapping: (I) it is often much cheaper than intensive trapping operations and (ii) it allows for multi-predator control (Brown *et al.*, 1998). Stoats are susceptible to secondary poisoning as they feed on rodents and scavenge possum carcasses; both species are targets of 1080 and brodifacoum poisoning operations (Brown *et al.*, 1998; Murphy *et al.*, 1998a). Murphy *et al* (1998a) also found that a higher proportion of female stoats had brodificoum residue in their livers than males did. This is a

reflection of differences in diet between the sexes and suggests that secondary poisoning could be a useful management tool against female stoats that are difficult to trap in the spring (Dilks *et al.*, 1996).

The major disadvantages of secondary poisoning are that (i) it relies on each stoat ingesting a sufficient amount of poisoned material to receive a lethal dose, therefore it's success is dependent on a large proportion of the prey species becoming contaminated (King *et al.*, 2001). (ii) It requires extensive, uncontrolled environmental contamination to be effective; however, widespread use of poison is becoming less publicly acceptable (Murphy *et al.*, 1998a). DOC does not currently use secondary poisoning as an official control tool because it is not species specific enough and other non-target species (including native birds) are potentially at risk.

Poisoning campaigns directed at stoats are much more target specific so less likely to affect native species, such as morepork (*Ninox novaeseelandiae*), and are less labour intensive (Dilks, 1997). Poisoned hens' eggs injected with 1080 (sodium monofluoroacetate) or diphacinone (an anticoagulant) have been trialed at bait stations with up to an 85% reduction in egg take following the operation (Spurr, 1995). Poisoned eggs have been found to be more effective than trapping to control stoat populations in some areas (Miller and Elliot, 1997). However inconsistent dosages and reluctance to actually eat bait have caused problems with past trials (Dilks, 1997). Other less conventional control methods trialed include ultrasonic devices, but both commercially available brands failed to repel stoats from a food source (Spurr, 1997).

1.2.5 Trapping

Trapping as a hunting or control method has been practised intentionally since prehistoric times (Bateman, 1988). The species targeted through trapping have been valued as a source of food or material (in many cases both), or they have been perceived as a threat to humans and resources they value (e.g. domestic stock, grain stores). Stoats in their 'ermine

condition' (winter pelt) were highly valued as furbearers, so have been commercially harvested in Russia for many centuries (King, 1989a). Stoats have been trapped on game estates in Britain since the 19th century to preserve game bird stocks for recreational hunting (King, 1989a).

Trapping is the most commonly used method to control stoats in New Zealand (King, 1994a). The benefits of trapping, as opposed to other control methods, is that the number of individuals removed is known, it can be used to monitor population trends, it provides information on the predator guild in the area and there is less public resistance to it than poisoning (King and Edgar, 1977). Trapping can be made species specific and those non-target species that do perish in traps are normally regarded as pest species in their own right. The disadvantages of trapping are that it is very labour intensive, which in turn increases the cost of the operation, not all animals are equally trappable and the target species must be correctly identified so that the correct trap type is used (Ratz, 1997).

Gender, age, time of year and previous experience affect individual stoat trappability (Speed, 1997; Alterio *et al.*, 1999). It has been well documented that trapping studies produce a male biased sample (King, 1975a; Buskirk and Lindstedt, 1989; Dilks *et al.*, 1996), although there are some exceptions (King, 1980). The reasons for this include trap spacing (relating to differences in home range size), likelihood of detection, stage of the breeding cycle, and dispersal characteristics. To further complicate this there is evidence that female stoats are more difficult to trap while they are producing and raising a litter (King, 1983b). The practice of running trap lines along roads and tracks may further bias samples towards males as it has been observed that female will avoid roads while males prefer them (Murphy and Dowding, 1994).

Trappability varies both within and between years. Seasonal variations may relate changes in activity patterns, for example males altering their movement patterns as they search for mates, or females rearing young (Erlinge and Sandell, 1986). Also stoats, like most animals, are more susceptible to trapping in times of low food abundance, especially

when baited traps are used (Alterio *et al.*, 1999). Conversely baiting traps may have less influence in periods of high food abundance.

Even when stoats are detected in an area, trapping may not be successful (Crouchley, 1994; Murphy and Dowding, 1995; Dowding and Murphy, 1996). The percentage of stoats that are trappable has been estimated at as low as 50% of the population (King, 1989a). While the actual proportion of untrappable animals may not be this high, several studies have shown that trapping operations may not remove all individuals known to be in the area (King and McMillan, 1982d; Crouchley, 1994; Murphy and Dowding, 1995). It is likely that those stoats not recaptured but still present in an area had been influenced by their initial capture experience. Other individuals are seemingly not deterred by capture and having identified traps as a source of food, will be recaptured regularly (C. Gillies *pers. comm.*).

The spacing, layout and positioning of traps have a substantial influence on the success of any control operation (King, 1994a). Trap spacing affects both the total number of stoats caught and the number of females caught, because the proportion of females caught decreases as the distance between traps increases (King, 1980). The overall aim of a study (i.e. intensive protection of a small area or population reduction over a large area) and the resources available for it partly dictates spacing. Areas that have had the resident adult populations removed will often have high reinvasion rates as they act as sinks for dispersing juveniles (Murphy and Dowding, 1994; King, 1994a). As a result, trapping rates are often higher on the edge of a grid than in its centre (Dilks *et al.*, 1996)

Trials conducted in the Dart Valley concluded that perimeter trapping removed a similar number of stoats as rapidly as grid trapping (Lawrence and O'Donnell, 1999). However mohua productivity, which would have been the best indication of the trials' success, was not monitored. Previous trials in the same area had shown that grid trapping substantially increased breeding success of mohua, but line trapping offered no protection

and that more stoats were trapped on the perimeters of a trapping grid than the internal lines (Dilks *et al.*, 1996; O'Donnell *et al.*, 1996a; Lawrence and O'Donnell, 1999).

Trap positioning has a substantial influence on its success. Many trapping operations find that most animals are caught in a few traps, while most others are left untouched (Dilks *et al.*, 1996)(Maxwell, *et. al* 1998, in (Griffiths, 1999)). Microsite analysis has been carried out to try and identify common features of successful sites but this has had limited success (Dilks *et al.*, 1996)(M. Maitland *pers. comm.*). Trapping guides suggest placing traps along well used trails or access routes, however it takes considerable experience to identify these (King, 1973a; King, 1980; King, 1989a). As stoat and prey distribution are often correlated, areas of high prey abundance or likely prey den sites should be targeted (Paton, 1997). Undisturbed sites often catch more animals than those close to areas of human activity do. This pattern has been observed in the mainland traps surrounding Maud Island (South Island, New Zealand), and could be due to high densities of preferred prey species such as rats in undisturbed areas (Paton, 1997).

Most trap efficiency studies have found that catch rates increase when traps or tracking tunnels are baited (King, 1975b; King and Edgar, 1977; Murphy *et al.*, 2000). Dilks *et al.* (1996) found that the most attractive baits were hens' eggs and mice, while a bait comparison trial in the Tongariro Forest conservation area (North Island, New Zealand) found that egg pulp was a superior bait to both sardine based cat food and hens' eggs (Martin, 1997). Captive stoats readily ate fresh meat baits but paid little attention to long life baits, such as cat food or dog biscuits (Spurr, 1999). Other commonly used baits include fresh rabbit, chicken or rat (fresh or freeze-dried). The major disadvantage of using these types of baits is that they become degraded fairly rapidly and need to be replaced regularly, with the exception of freeze-dried rat. Fresh meat may also attract more non-target species, such as rats, and is more susceptible to insect damage (pers. obs.). Hens' eggs are currently the most commonly used bait, as they retain their attractant properties for much longer than most meat baits and also provide a visual lure (King *et al.*, 1994b;

Dilks *et al.*, 1996; Spurr, 1999). Recent trials in the Rotoiti recovery project (South Island, New Zealand) caught significantly more stoats in tunnels baited with white eggs than tunnels baited with brown eggs so all traps in this area are now baited using white eggs (M. Maitland pers. com.).

Traditionally lures have been based on the scent of prey species. Rabbit or bird viscera may be smeared over traps and in the area surrounding them (Vershinin, 1972; King, 1973a; King and Edgar, 1977). More recent work in this area has focused on developing long-lasting scent lures based on the compounds found in anal sac secretions. Clapperton *et al.* (1994) found that while these lures were effective in attracting ferrets they had little success in attracting stoats, and may have repelled juveniles present during the trial. Further pen trials comparing food odours with a variety of prey or conspecific synthetic odours found that none of the synthetic odours attracted stoats, although due to the small sample size used these trails could not be considered conclusive (Spurr, 1999). Recent trials on sound lures suggest that chick, mouse and stoat calls may be effective lures, while distress calls of common introduced bird species did not attract captive stoats (Spurr and O'Connor, 1999). The quality of recordings may also influence the success of a particular sound lure (Spurr and O'Connor, 1999).

It has been suggested that the most effective lure would be one that is highly attractive to female stoats in spring, as this would substantially reduce the amount of trapping needed later once juveniles became active (Dilks *et al.*, 1996). An example of this is male stoat scent; a study of stoats in Ireland found traps baited with male stoat anal scent gland secretions caught only female stoats (Sleeman, 1989).

1.2.6 Trap type

The Mark IV and VI Fenn traps were introduced from Britain in 1972 by C. King and are still the most commonly used kill trap for stoats in New Zealand (King, 1994a). Fenn traps are most often used as a double set to decrease the likelihood of a stoat avoiding capture

once they approach the trap (Speed, 1997)(C. Gillies pers. comm.). Timms traps, Conibear traps and Victor No. 1 soft-catch traps have also successfully caught stoats when used as part of a multi-predator control operation (Ratz, 1997) (E. Murphy pers. comm.).

Overseas, a variety of trap types are used to trap mustelids. In Britain the main trap types used are Fenns, Springers (copies of Fenns) and BMIs (110 and 116), which are also known as conibears (I. Inglis pers. comm.). In Canada the only officially sanctioned trap for weasels is the Victor rat-trap (web site). Trappers in the former USSR also use cherkan snares in some regions (Vershinin, 1972).

As the public becomes more aware of animal welfare issues and how they relate to wildlife management, traps have to meet more stringent humaneness requirements. The introduction of Fenn traps to Britain and New Zealand was in response to growing public dissatisfaction with the inhumaneness of Gin traps. A correctly caught stoat in a Fenn trap is killed by a double break of the back (King, 1973a). Fenn traps were found to cause far fewer gross external injuries, fewer animals escaped from them and time to death was swifter than with Gin traps (King, 1981). However, recent trials conducted by Landcare Research have shown the Mark IV and VI Fenn traps, which are the most commonly used stoat control device, to be inhumane as defined by current legislation (National Animal Welfare Advisory Committee (NAWAC) draft guidelines) (B. Warburton pers. comm.). They fail to render an animal unconscious after three minutes. Further trials to assess the humaneness of other traps currently in use, or those traps which have the potential to be used for stoat control, such as the Victor rat trap, are currently being conducted by Landcare Research.

Recent legislative changes (Animal Welfare Act 1999 s.36) now require live traps to be checked daily but do not specify a minimum inspection period for kill traps. This change has the potential to substantially decrease the labour costs of a control operation, as traps could be checked weekly or even monthly in areas of low stoat abundance. The major problems with increasing the period between inspections is that once a trap has been

sprung it is unable to catch any target animals which come into contact with it before the next inspection. During periods of low stoat abundance this may not be a problem as more frequent trap inspections would not increase the number of individuals caught. However in periods of moderate to high abundance (e.g. during a mast year or while juveniles are dispersing) more frequent inspections would be necessary or trapping may not provide effective control. As trapping operations often observe that a few traps will catch a disproportionate number of stoats, less frequent inspections may reduce the operations success if those traps are unable to catch for long periods of time.

1.2.7 Tunnel Type and Design

Tunnels are necessary with many types of traps to exclude non target species, orientate the stoat towards the trap, and protect both the trap and any bait from weathering too quickly or being damaged (King, 1973a; Warburton, 1997). Many of New Zealand's larger or more inquisitive native bird species, such as kiwi, weka, kakapo and kaka, would be at risk from traps if the traps were not housed in a protective tunnel. Other introduced species such as possums and hedgehogs may also need to be excluded because Fenn traps, in particular, may be more likely to injure rather than kill the animal.

Interference by non-target species not only poses the risk of injury or death to individuals but it also renders the trap ineffective for capture of the target species. Trap efficiency can also be affected if the trigger mechanism is hindered by rust or debris (King, 1994a). Tunnels increase the life of the bait by protecting it from the elements and restricting access to all except those species able to enter.

Tunnels also help position the target species in the correct place for a humane kill. If an animal is not struck in the right spot it will not be killed quickly or may escape. The effectiveness of the trap can be severely compromised if the animal is allowed too much movement within a tunnel. Tunnel design also tries to minimise the likelihood of a stoat evading capture once it has entered. This is one reason why most Fenn traps are set as pairs

as stoats will often avoid the first trap (C. Gillies pers. comm.). A well-designed tunnel should encourage a stoat to investigate the tunnel and should not provide any opportunity to avoid the trap once it has entered.

Tunnel designs currently in use are based around the Fenn trap and its' kill mechanism. Consideration as to how tunnel design might affect the animals' behavioural response is limited by the constraints placed on the tunnel by trap requirements. Almost all tunnel designs have been based around a 'suck it and see' approach, sometimes with less than satisfactory results (B. Warburton pers. comm.). For example, a live capture tunnel-trap developed for ferrets had an entrance that excluded some of the largest males at certain times of the year (C. O'Connor pers. comm.).

Trapping methods and protocol in New Zealand have relied heavily on other counties' experience, especially game estates in Britain. In Britain, tunnels are made to look as natural as possible, with any scrap pieces of wood, drainpipes, bricks or logs used to create a covered runway (King, 1973a). Trapping guides suggest that any narrow covered runway will do (King, 1973a). As local trapping expertise has grown these methods have been refined for New Zealand conditions. Designs have been altered to guide the animals over the trigger plate, and most tunnels have floors because the traps are less likely to become clogged with debris and are easier to set (Dilks *et al.*, 1996). Tunnel design in New Zealand is based around portable tunnels, so alternative construction materials have been tested in the field.

Trapping tunnels are constructed primarily from wood, because it is a readily available and inexpensive material. Wooden tunnels are also less susceptible to damage from inquisitive possums or kaka, and are easy to check once in place. However because of their weight and size they require vehicle access or a lot of labour to set out (Maxwell *et al.*, 1997). This contributes substantially to the cost of a control operation. Alternative tunnel materials used to decrease tunnel weight and improve trapper efficiency include aluminium, mesh, plastic ("Phillproof" plastic covers) and corflute (Maxwell *et al.*, 1997).

Several studies on stoat tunnel and trap type preferences have been carried out in the field as part of ongoing control operations (Dilks *et al.*, 1996; Maxwell *et al.*, 1997). In most cases they have found no significant differences in tunnel type preference. Trials in the Hawdon and Eglington valleys (South Island, New Zealand) found no significant difference in capture rates between wooden open and closed-ended traps; however, tunnels with bases were easier to check (Dilks *et al.*, 1996). Trials of poison tunnels in the Hollyford and Arthur valleys (South Island, New Zealand) found a significant preference for the wooden tunnel over the 'novaflow' piping tunnel, but not the other types trialed (Maxwell *et al.*, 1997). However, the report gives no indication of the dimensions of the different tunnels, and the 'novaflow' tunnel was closed at one end while the other three tunnels were of a run-through design, so inferences on the suitability of plastic cannot be made based on the results of this trial. The study also tested six different trap cover types, however, no statistically significant preferences were found (Maxwell *et al.*, 1997). Other control operations have successfully used plastic covers to house poisoned eggs (Miller and Elliot, 1997).

Limited work done has been done on the behavioural responses of stoats to different types of trapping and tracking tunnels (Spurr and Hough, 1994). Although some preferences have been observed in the field, no significant variation has been found in subsequent trials. Spurr and Hough (1994) compared the behaviour of stoats towards wooden and aluminium trapping tunnels in both the pen and field, and found that videoed animals entered into both tunnel types readily. This study was prompted by a DOC trapping programme using a paired comparison of these two tunnel types, which caught stoats in the wooden tunnels only. Although the animals may have had a preference to enter the wooden tunnels first, the design of the DOC experiment did not take into account that if no choice was available the animals would have entered the aluminium tunnels and been caught regardless.

Trappability has been identified as a major contributing factor to the success of control operations, however, little attention has been paid to the effect tunnel design may have on an individual's entry behaviour. Some studies have recognised that it can influence capture rate so have called for improved tunnel and trap designs (O'Donnell *et al.*, 1992; Alterio *et al.*, 1999). The scant knowledge gained so far from field trials on the effects of tunnel design suggests that it may influence entry behaviour, but provides little indication of which factors are most critical. The available literature is of little use to trap designers who may want to move away from the principles of the Fenn trap and need a tunnel design that meets their requirements.

A self-resetting, repeat kill stoat trap is currently being developed at Lincoln University. As it uses a different mechanism to the Fenn trap, it is not suitable for use with currently available tunnel designs. The information gained from this study on the influence of tunnel design on stoat entry behaviour will assist in designing a tunnel, which is appropriate for use with the new kill trap.

1.3 Aims and objectives of thesis

The aim of this thesis was to design a tunnel that would maximise the proportion of stoats encountering the kill device, while minimising the risk to non-target species.

The specific objectives were to:

- Determine the effects of tunnel diameter, length and end type on the entry behaviour of stoats in outdoor pens.
- Validate the pen results in the field.
- Develop a method for sampling stoat hairs at tracking tunnels, with a view to the development of a population assessment-monitoring method based on hair analysis.

CHAPTER TWO

General Methods

This chapter presents the general methods applicable to all four pen trials (Chapters 3, 4 & 5).

2.1 Animal Husbandry

The trials were conducted at the Landcare Research Animal Facility observation pens, located to the west of Lincoln Township. The observation area is a hexagonal design comprised of six large pens (each pen is approx. 10 x 5 x 2 m) (Plate 2.1). These cages are constructed of 10 mm weld mesh, with a metal skirt dug down 300 mm, which made them 'stoat proof'. In the centre of the pens is an observation room from which all six pens are visible. All filming was done from this room and all excess equipment was housed in it during the trials. Each pen contained an overhead 300-watt halogen light for observations at night.

All trials used stoats caught from various sites in the Canterbury region. Prior to the trials, these animals were individually housed in wire cages (0.6 x 0.9 x 1.5 m), containing a nest box with shredded paper bedding (Plate 2.2). Stoats were fed an alternating diet of beef or horse mince and a dead day old chick, and had free access to water. They were feed between 10 am and 12pm daily. All stoats were weighed and checked for general health throughout the course of the trials. The stoats were transferred between their holding cages and the observation pens in their own nestbox to minimise stress for both the animal and handler. The Lincoln University Animal Ethics Committee approved these trials prior to commencement (Project N°. 833). During the course of the trials stoats that were not being observed were also used for other Landcare Research experiments.

Plate 2.1 Landcare Research Observation Pens

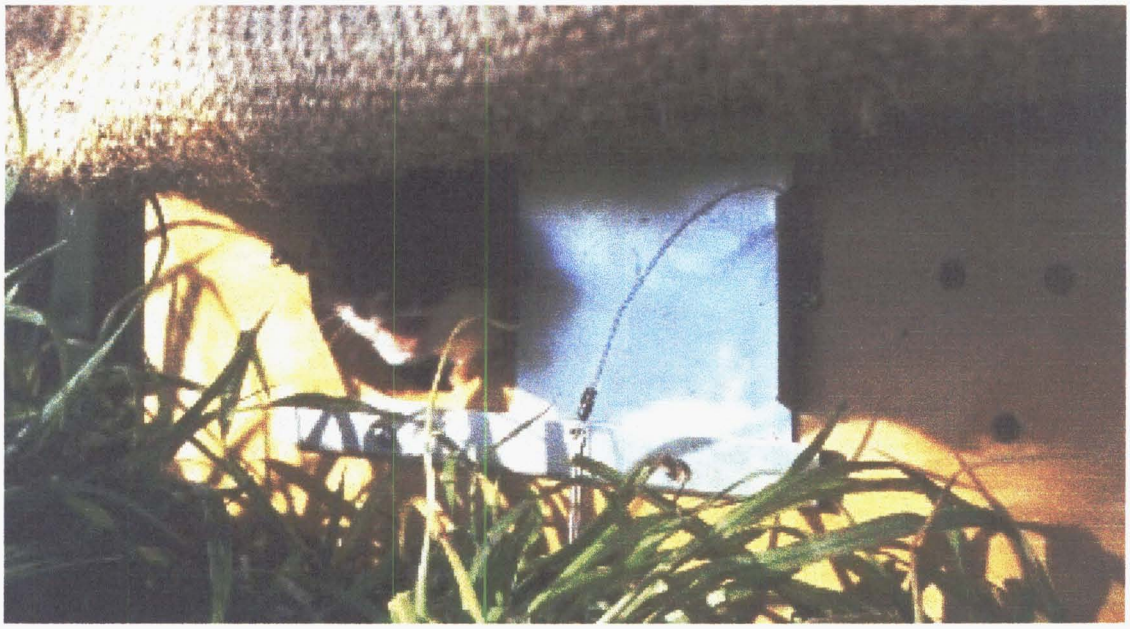

Plate 2.2 Stoat at entrance of its nest box

2.2 Trial Design

Each trial period comprised a minimum of two days (48hrs) acclimatisation to the pen, followed by three nights of testing. Each stoat was presented with one tunnel type per night over the three night test period. The test period was extended in some instances, as trials were not run in bad weather (e.g., heavy rain) or when other activities in the pen area would have disturbed the animals. Each stoat was randomly assigned to one of six sequences prior to testing, which determined the order that the tunnels were presented to them. In some cases this meant that they received the tunnels in the same sequence during subsequent trials. As there were 12 stoats available each sequence was replicated twice. Each tunnel was placed approximately 3 m from the inner wall of the observation pens and an equal distance from both of the side walls (approximately 2.5 m). The tunnels were placed in the same position within the pens during all four trials.

Three stoats were trialed simultaneously, with each being subjected to one test period per trial. At the conclusion of each trial period the stoats were removed from the observation pens and placed back into their individual cages. In most cases this task was easily completed the day after the final night of testing, however, in some cases it took up to three weeks to recapture the stoats.

All stoat odours were removed from the tunnels between each test. The tunnels were washed with 'Stericide' cleaning liquid and then soaked for 10-20 minutes in 'Vircon' disinfectant. These cleaning substances were being used during the day-to-day husbandry of the stoats so were familiar odours to them. After being cleaned the tunnels were only handled by people wearing gloves. These precautions were taken to minimise any confounding affects that human or stoat odours might have had on the stoats' behaviour.

It was impractical to make accurate direct observations through the night of three stoats simultaneously; so video recordings were used to collect the data. Due to the speed at which stoats can move video recorders also allowed for much more detailed behavioural observations. The camera focused on a $1m^2$ area around each tunnel, so the details of each behaviour could be accurately recorded. Each stoat was videoed over a 12-15 hour period using time-lapse Mitsubishi HS-5424 VCR's and TEAC ASX-E180 VHS tapes. Videoing commenced between 4pm and 6pm and finished when the video ran out, normally between 6am and 8am. The decision to observe the stoats at night was based on initial 24h filming and personal observations, which indicated that the human activity in the area during the day often curtailed the stoats' activities.

2.3 Analysis

Each videotape was reviewed as soon as possible after the trial to monitor the animals' responses to the different variables they were presented with. The data recorded were the initial entry type into the tunnel (Table 2.1); the number of times each stoat entered the tunnels, the proportion of the stoat's body that entered the tunnel, and the duration of each behavioural response. The statistical analyses used are discussed in the relevant chapters and all means are presented ± 1 S.E. Data were analyzed in Minitab 12 (Ryan and Joiner, 2001).

Table 2.1 Description of behavioural categories used in all pen trials.

Behaviour	Sub-behaviour classifications	Description
Approach		An approach to within one body length (c. 30cm) of the tunnel, provided the stoat was orientated towards the tunnel.
Smell		A stoat smelling any part of the tunnel, which may include moving the tunnel.
Climb		A stoat placing one or more of its paws on the tunnel.
Alert posture		A stoat balancing on its hind legs while observing the surrounding area.
Entry		Any entry into the tunnel, classified by the proportion of the animals' body that entered the tunnel.
	Partial Head	Point of nose to ears.
	Head	Ears to shoulders.
	Partial Body	Shoulders to hips.
	Body	Past the hips, but not necessarily including the tail.
Exit		The method of exit from the tunnel.
	Reverse	The stoat exits backward from the same entrance it entered the tunnel from.
	Turn	The stoat exits forwards from the same entrance it entered the tunnel from.
	Forward	The stoat exits through the opposite end from the one it entered (applicable to Experiment 2 only).

CHAPTER THREE

The effect of tunnel entrance diameter and end type on stoat entry behaviour

3.1 Introduction

The design of tunnels used for vertebrate pest control is restricted by the requirements of the kill trap mechanisms they are used with. Factors that may encourage or discourage the target animals' entry has been a secondary consideration after establishing dimensions that would allow the trap mechanism to function. In New Zealand, Mark IV and Mark VI Fenn traps are the most commonly used kill traps for stoat (*Mustela erminea*) control (King, 1994a). Thus, tunnels have remained large through necessity to accommodate the Fenn traps. However, emerging new technologies using alternative trap designs or methods other than traps mean that past restrictions on tunnel design are lifted. It consequently becomes relevant to ask what's the optimum tunnel design for both stoats and new traps.

There has been no previous research on the effects of current trapping and tracking tunnel dimensions on the entry behaviour of stoats or any investigation of their reactions to tunnels with alternative dimensions (i.e. larger or smaller tunnels). There is also no information available on the effect of end type in tunnels smaller than 150 mm diameter. A new kill trap for stoats is currently being developed at Lincoln University. It requires information on these subjects to assist in designing a trapping tunnel that satisfies the requirements of the trap, while maximising the number of animals that will encounter the trap.

In the wild, stoats excel in hunting small mammals in confined spaces (King, 1989a). Their ability to enter holes only slightly larger than those used by mice means that few refuges available to their prey (King, 1984). In Canada, Simms (1979) found that all

stoats could enter 70% of subnivean (under snow) vole tunnels (22-28mm) and smaller females could enter up to 90%. Experiments conducted prior to the erection of the Karori Wildlife Sanctuary fence found that female stoats were able to pass through 25 mm wire mesh but that all stoats were excluded by 12 mm weld fab (Fuller and Gorman, 1997). Field workers have often found dens with entrance diameters of 30 mm (Dowding and Murphy, 1996). Hence, stoats frequently enter openings with small diameters.

In New Zealand, stoats are key predators on mohua (*Mohoua ochrocephala*) and yellow crowned parakeet (*Cyanoramphus auriceps*), which are both hole nesting species (O'Donnell, 1996b). The smallest entrance hole found was 25 mm for both species (Elliott *et al.*, 1996). Therefore stoats would be able to gain access to all nest holes. Stoats are also known to predate juvenile kiwi, the average burrow entrance for most kiwis are 90-150 mm in diameter (Folch, 1992). Introduced species, such as the European rabbit (*Oryctolagus cuniculus cuniculus*), house mouse (*Mus musculus*) and Norway rat (*Rattus norvegicus*), which provide a major part of the stoats' diet, inhabit burrows and crevices with a wide variety of entrance sizes, usually larger than 25 mm. The average burrow diameter for rabbits is approximately 120 mm-250 mm (B. Reddiex pers.com.).

Entrance diameter of holes offers one initial cue to stoats of potential prey type; length is not always discernible from an initial inspection but entrance size is immediately obvious and gives an indication of possible prey species. Olfactory cues provide a more accurate guide, however entrance size may form part of the initial search image if a predator is searching for a particular prey species (Wilson *et al.*, 1998). Weasels and small stoats are occasionally caught in Longworth traps, set for small mammals. One possible reason for this is that the entrance is a small hole, which resembles the entrance to a small mammal den (Sleeman, 1989).

Various factors should be considered when trying to optimise tunnel design for any given situation. These include the ability of the tunnel to invite further investigation, willingness of the target animals to enter the tunnel far enough to be caught in the trap,

exclusion non-target species, trap and trapper efficiency, trying to ensure a humane kill, and protection of the trap from interference and weathering.

Once set, the Mark IV Fenn trap forms a 150 x130 mm square (King *et al.*, 1994b). The tunnel dimensions recommended for this trap by DOC include an internal width of 150 mm and a height of 200 mm, with mesh ends to exclude non target species, but allow stoat access (King *et al.*, 1994b). These dimensions allow Fenn traps to be fitted into the tunnels without obstructing the action. Ideally, the tunnel should be small enough to make jumping over the trap (without landing on the pressure plate) or squeezing past it difficult for the target species. Most trapping tunnels contain two Fenn traps, as this decreases the likelihood of a stoat entering the tunnel without getting caught (C. Gillies pers. comm.). Trap covers used in the Tongariro Forest Conservation Area were narrowed from 200 mm to 165 mm in diameter to minimise the possibility of stoats jumping over the traps. In 14% of captures in the 200 mm tunnels stoats were exiting the tunnels, meaning they had successfully avoided the first trap, however narrowing the covers may have eliminated this (Martin, 1997).

Tunnels large enough to accommodate Fenn traps will not prevent many non-target entries unless the entrance is restricted through the used of excluders. Exclusion of non-target species from trapping tunnels with a large diameter (>100 mm) is often achieved through the use of close-set bars across the entrance or a mesh end with a smaller entrance cut into it (Dilks *et al.*, 1996; Short and Reynolds, 2000). Two separate British studies, one involving several native mammals (including stoats), and another using rats, concluded that it was better to restrict the entrance of a tunnel with vertically set sticks than a solid sheet with a hole cut in it (Short and Reynolds, 2000)(I. Inglis, pers comm.). Short and Reynolds (2000) also found that tunnels with excluders did not significantly reduce stoat captures. An additional benefit of excluders is that they may assist in orientating the animal towards the trap (Maxwell *et al.*, 1997).

Reducing the diameter of the entrance can remove the need for excluders. The Edgar live trap has internal dimensions of 140 mm (height) x 108mm (width) and the connecting hole between the nest box and tunnel is 45mm in diameter (King and Edgar, 1977). Although many larger species can enter the trap, the small diameter of the nest box entrance successfully excludes most non-target species with the exception of rodents (King and Edgar, 1977).

The standard tracking tunnels used by DOC has an entrance diameter of 110 mm (height) x 80 mm (width) (Murphy *et al.*, 2000). Although this method is commonly used to detect the presence of stoats, information on other species present in the area is also gained, because larger species such as hedgehogs are not restricted from entry (Gillies and Williams, 2000). In this case using a larger size that does not inhibit non-target entry is beneficial.

The effect of tunnel end type has been investigated in several trials on general tunnel design (Dilks *et al.*, 1996; Maxwell *et al.*, 1997). Poisoned egg trials found that blind-ended, Novaflow tunnels were visited less and had a lower egg take than the three other tunnel designs trialed, which were all open at both ends (Maxwell *et al.*, 1997). In subsequent trapping tunnel design trials, Maxwell *et al.* (1997) found no significant difference between open and closed ended tunnel types, although open ended tunnels did have the highest number of captures. An earlier study by Dilkes *et al.* (1996) also found no difference in capture rates between run-through and single-entrance tunnels. However, because both these studies were field based they had low statistical power. Therefore it would have been difficult to obtain significant results because of low stoat densities. These trials give no indication of possible effects of end type on stoat entry behaviour into smaller tunnels.

At present, a run-through tunnel is advocated by DOC as the best practice because it houses two traps, which is thought to increase the likelihood of capture and reduce the chance of not capturing an animal because a trap has already been sprung. Yet it requires a

longer tunnel (more building materials) and double the number of traps. The large size (and consequent increase in weight) also makes these tunnels more labour intensive, which reduces trapper efficiency. In reality the likelihood of capturing two stoats in one trap, if it is serviced regularly, is reasonably low.

Tunnels with two traps may increase the capture rate prior to juvenile stoats dispersing, when they are hunting in a group (B Warburton pers. comm.) or during a stoat eruption after a mast year. At this time it is more likely that a stoat may encounter the tunnel before it can be cleared as stoat densities are at their highest and siblings may follow each other into a tunnel.

The two experiments reported in this chapter examine stoat investigative behaviour in relation to tunnel entrance diameter and end type. The first aim was to observe stoats' behavioural reactions to a series of different diameters so as to determine how diameter may affect stoat entry behaviour. The second aim was to study the affect of end type on stoat entry behaviour at a series of different diameters.

3.2 Methods

3.2.1 Experiment 1 - Entrance width of closed-ended tunnels.

Tunnels were constructed out of dark grey, storm or waste PVC drain pipe (50 and 150 mm - AHI Garnite Class B, 100 mm – Marley 100.05 PVC) (Plate 3.1), blocked at one end with a circular metal plate. The three tunnel diameters tested were 50, 100 and 150 mm. These diameters were chosen to cover the range of diameters already in use with other trapping tunnels. It was hoped that these size differences would be sufficient to detect any variability in response to the entrance diameters. An initial length of 400 mm was chosen, as this was long enough that the animals had to fully enter it in order to reach the end of the tunnel. Chapter 2 contains information on the general trial design and pen set-up.

Twelve stoats were used in the experiment; six males and six females. These stoats were experimentally naïve prior to the experiments and had been in captivity for varying time periods ranging from 25 days to 13 months (see chapter 2 for husbandry details).

3.2.2 Experiment 2 - Entrance width of open-ended tunnels.

In this experiment, the diameters used were the same as in experiment 1 (i.e. 50 mm, 100 mm and 150 mm). The tunnels remained 400 mm in length and were constructed out of the same piping. However, they were not capped in this experiment, which allowed the stoats to enter and exit from both ends of the tunnel. The 12 stoats used in experiment 1 were reused in this experiment. However, only 10 of the 12 sets of results could be used in the final analysis as stoat #12 escaped into stoat #7's pen during the trial. All stoats had a minimum of seven weeks rest between Experiments 1 and 2 and were regularly weighed and inspected visually during this time to ensure they remained in good health.

3.2.3 Statistical analysis

The first entry type into each tunnel type was analysed by ranking each entry behaviour on a scale from 0-4, 0 meaning the stoat never entered the tunnel and 4 being a full body entry on its first encounter. Partial head, head, and partial body entries were assigned ranks from 1-3 respectively The mean entry scores for each tunnel type were then compared using a one-way ANOVA. The same analysis was also applied to the furthest entry made. This was defined using the same five entry categories, as the greatest proportion of stoats' body, which entered the tunnel. As an example a stoat which made a body entry into a tunnel at some point during the night was given a score of four, while a stoat who only ever made a head entry was given a score of two.

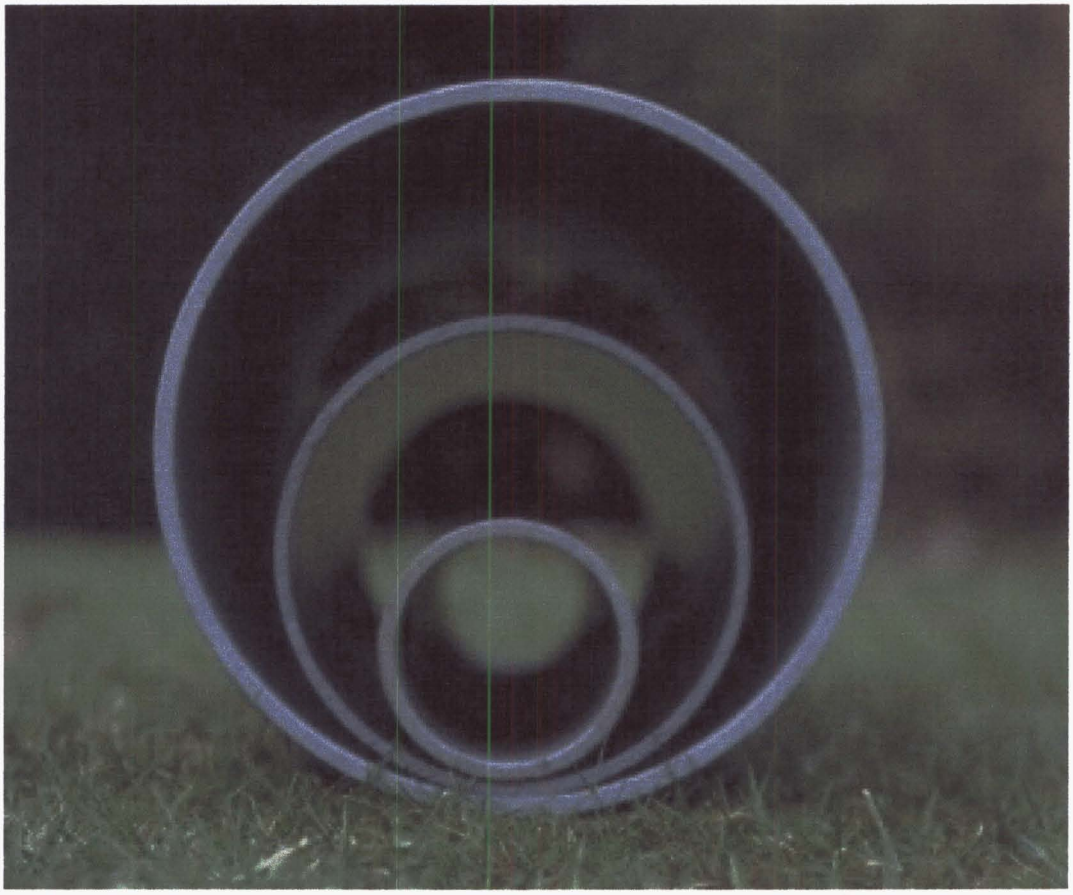

Plate 3.1 The three open-ended tunnels (from middle 50 mm, 100 mm and 150 mm).

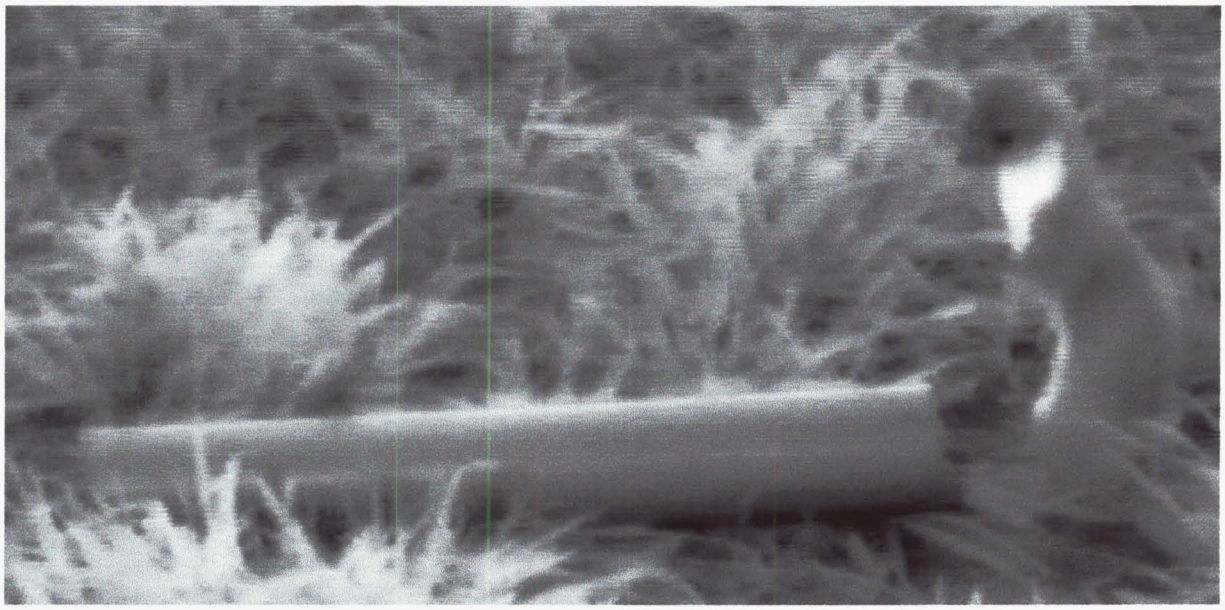

Plate 3.2 Stoat in alert posture in front of 50 mm open-ended tunnel (image captured from video tape).

Factors affecting entrance behaviour were assessed with a General Linear Model (GLM) with night, trial and diameter treated as categorical variables. The entry:approach ratio data, investigative behaviour and exit data were all analysed using a two-tailed t-test or one-way ANOVA, depending on the number of groups being analysed.

3.3 Results

3.3.1 Experiment 1 - Entrance width of closed-ended tunnels.

Stoats would be observed for the first time (note camera did not view entire pen) between 1700 h and 2000 h, although occasionally individuals were not seen until after midnight. Usually, the stoat would then approach the tunnel. The boldness of approach varied between individuals but each stoat tended to be most hesitant (e.g. slow approach, spend more time investigating outside of tunnel) on the first night of testing, however, this hesitation only lasted for the first few approaches. Once the stoat had approached the tunnel it either moved away or approached more closely and made contact with it by smelling different parts of the tunnel. At this point the stoat would again either move away or continue investigating the tunnel by smelling, climbing or entering it (Plate 3.2). Seventy five percent of stoats entered the tunnel on their first approach and all stoats had entered within four approaches (Table 3.1). The initial entry type made into the tunnel did not differ significantly between the three tunnel diameters (Table 3.2).

Table 3.1 Counts of the first response of stoats upon initial encounter with each tunnel type (Closed n=12, Open n=10).

Entry Type	Closed Tunnels			Open Tunnels		
	50 mm	100 mm	150 mm	50 mm	100 mm	150 mm
Partial Head	0	0	1	0	1	0
Head	2	3	4	1	0	2
Partial Body	3	1	0	0	0	0
Body	4	6	4	8	6	7
No Entry	3	2	3	1	3	1

The initial entry was often followed by a period of high activity during which the stoat would move away from, and return to, the tunnel several times. A stoat would often perform multiple entries into the tunnel once they had approached it. Stoats entered 50 mm tunnels on 51% (±6%) of approaches, 100 mm tunnels on 42% (± 4%) of approaches and 150 mm tunnels on 49% (± 4%) of approaches. There was no significant difference between the entry to approach ratio of these three diameters ($F_{2, 35} = 0.93$, $p = 0.404$).

Table 3.2 The mean scores for initial entry and furthest entry made by a stoat for Experiments 1 and 2 (Closed n = 12, Open n = 10). A higher score indicates more body entries.

Tunnel Diameter and End type	Mean Ranks (± 1 S.E.)	
	Initial Entry	Furthest point
Closed 50 mm	2.83 (0.34)	3.75 (0.17)
Closed 100 mm	3.41 (0.25)	4.00 (0.00)
Closed 150 mm	2.67(0.33)	3.83 (0.16)
Open 50 mm	3.80 (0.20)	4.00 (0.00)
Open 100 mm	3.70 (0.30)	3.90 (0.09)
Open 150 mm	3.30 (0.36)	3.70 (0.30)

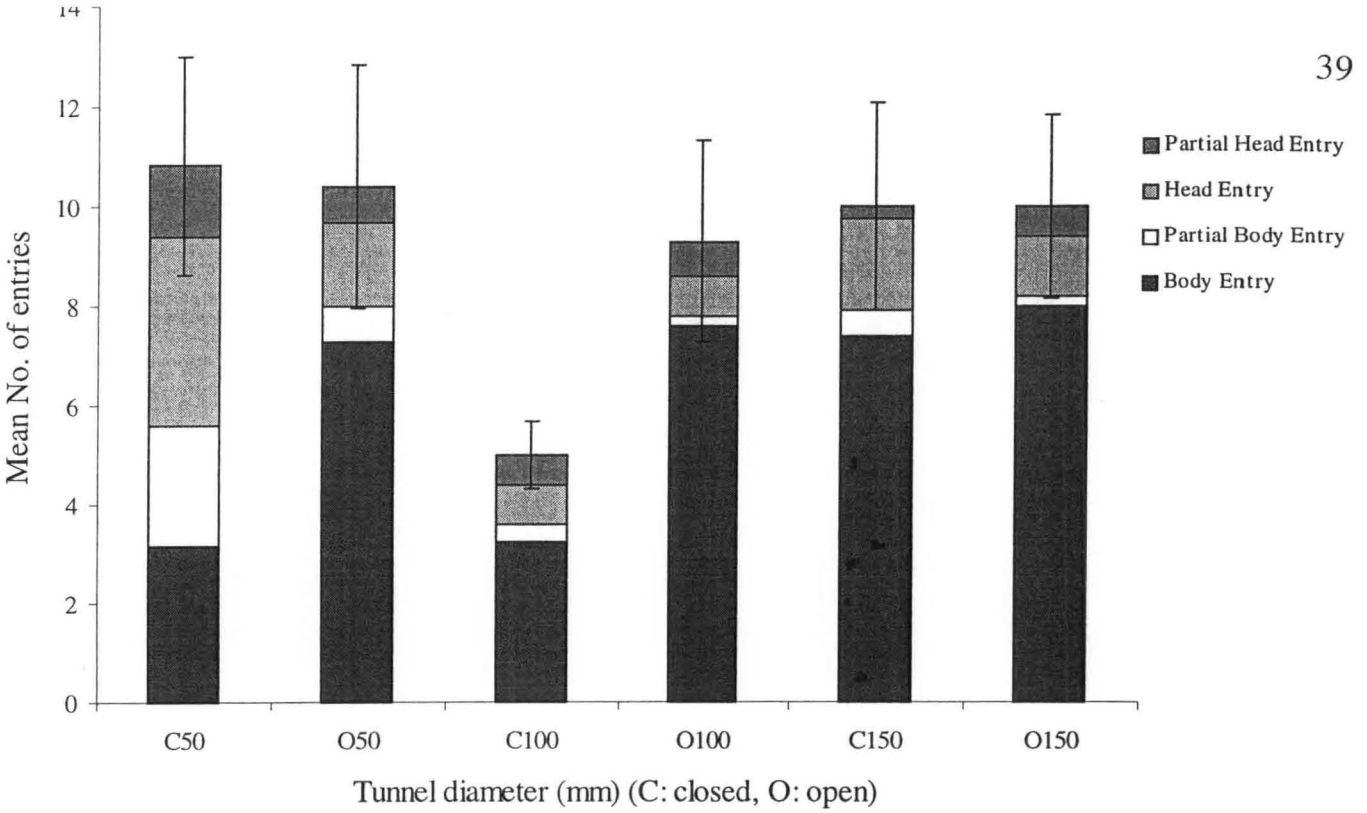

Figure 3.1 Comparison of cumulative mean entries per tunnel type (± 1 S.E.), with the proportion of each entry type shown, between closed and open-ended diameter trials (Closed n = 12, Open n = 10).

The high frequency of repeat entries into the tunnels highlighted differences in the way stoats behaved towards the three diameters. Diameter did appear to affect total entry rates however it was marginally non-significant (Figure 3.1, $F_{2, 32} = 3.14$, $p = 0.057$). There were fewer total entries into the 100 mm tunnel than into the 50 mm tunnel ($F_{2, 11} = 7.87$, $p = 0.017$) and probably fewer than into the 150 mm tunnel ($F_{2, 11} = 4.802$, $p = 0.051$). However, the proportion of each entry type that comprised the total entries was similar for the 100 mm and 150 mm tunnels. Body entries made up 64% of the 100 mm tunnels total entries and 75% of the 150 mm total entries, which was significantly higher than any other entry type (100 mm - $F_{3, 47} = 19.41$, $p < 0.001$, 150 mm - $F_{3, 47} = 9.56$, $p < 0.001$).

In contrast, stoats performed all four entry types with similar frequency in the 50 mm tunnel. When analysed by individual entry type, the 50 mm diameter tunnel has

significantly more partial head, head and partial body entries than either the 100 mm or 150 mm tunnels (Partial head - $F_{2, 35} = 4.20$, $p = 0.024$, Head -.$F_{2, 35} = 5.89$, $p = 0.007$, Partial body - $F_{2,35} = 10.92$, $p < 0.001$). The 50 mm and 100 mm diameter tunnels show a strong trend towards fewer body entries when compared with the 150 mm ($F_{2, 35} = 3.01$, $p = 0.063$).

Stoats were unable to turn in the 50 mm tunnel, whereas in the two larger tunnels they had the choice to either turn or reverse. When given the choice they turned 64 % of the time in the 100 mm tunnel and 76% of the time in the 150 mm tunnels. Stoats reversed out of 50 mm tunnels significantly more than out of the two larger tunnels, and turned in 100 and 150 mm tunnels significantly more than 50 mm tunnels (Turn $F_{2, 31} = 9.4$, $p = 0.001$, Reverse $F_{2, 31} = 13.6$, $p < 0.001$).

The frequency of investigative behaviours other than entries did not differ significantly between the three diameters (Table 3.3). However, the 150 mm tunnel was climbed on twice as often as the other two tunnels (50 mm and 100 mm). Stoats were often observed using the tunnels to maintain an alert posture by placing their front paws on top of the tunnel or climbing on top of it and then assuming an alert posture. Entry rate declined significantly during the three night testing period (Figure 3.2, $F_{2, 32} = 5.8$, $p = 0.021$), which suggests that the stoats were becoming habituated to the tunnels.

Table 3.3 Mean number of investigative behaviour performed towards each tunnel type, compared between closed and open-ended tunnels (± 1 S.E.) (Closed n = 12, Open n = 10).

Tunnel type	Behaviour		
	Approach	Smell	Climb
Closed 50 mm	13.42 (1.11)	21.50 (3.97)	5.75 (1.68)
Open 50 mm	11.30 (1.58)	9.20 (1.84)	11.80 (2.92)
Closed 100 mm	11.67 (1.11)	15.08 (2.01)	5.08 (1.32)
Open 100 mm	7.80 (2.02)	7.50 (2.09)	12.00 (2.47)
Closed 150 mm	16.58 (3.03)	21.17 (3.41)	10.42 (3.050
Open 150 mm	9.00 (1.46)	9.70 (2.59)	10.20 (1.80)

3.3.2 Experiment 2 - Entrance width of open-ended tunnels.

Eighty seven percent of stoats entered the tunnel on their first approach and all of the animals had entered by their fourth approach (Table 3.1). A stoat would often make multiple entries on one approach. However, a stoat would sometimes approach the tunnel and spent a long period investigating it without entering (even though it might previously have entered it). Stoats made some type of entry into a 50 mm tunnel on 51% (± 8%) of approaches. Stoats entered on 64% (± 9%) of approaches to a 100 mm tunnel and 67% (± 4%) of approaches to 150 mm tunnels. These differences in the entry rate were not statistically significant ($F_{2, 29} = 1.16$, $p = 0.33$).

Diameter had no significant affect on the frequency of repeat entries. There was no difference between the 3 diameters for mean total entries nor for any of the individual entry types (Figure 3.1). However, body entries were the most frequently performed entry type for all three diameters (Figure 3.1, all diameters $p<0.01$, 29d.f.). They comprised 70% of the total entries into the 50 mm tunnels and over 80% into the 100 mm and 150 mm tunnels.

Stoats were most likely to exit the tunnels by continuing forward rather than turning around or reversing. However, they were also observed exiting from the same end as they entered. Often, they would make a partial exit or at least investigate the opposite end of the tunnel, before exiting at the original entry point. Some animals would do this several times before exiting. The 100 and 150 mm tunnels had significantly more forward exits (70.5% and 65% respectively) than turn or reverse exits (100 mm $p=0.01$ and 150 mm $p < 0.001$). The 50 mm tunnel followed this trend with more forward exits (62.5% of exits), although this was not significantly different from the number of reverse exits performed. Stoats were more likely to reverse from the 50 mm tunnel (37.5% of exits) than the 100 mm or 150 mm tunnels (18.5% and 20% respectively), however again this was not a statistically significant effect ($p = 0.19$). Comparison of exit types between the three

diameters is limited by stoats being unable to turn around in the 50 m tunnels. Similarly, the frequency of other investigative behaviours did not differ significantly between the three diameters (Table 3.3).

3.3.3 Comparison of closed versus open-ended tunnels

A significantly higher percentage of approaches resulted in an entry into the open 100 mm and 150 mm tunnels (64% and 68%) than into their closed-ended counterparts (42% and 49%) (t_{11}=2.21, p = 0.050 and t_{13}=2.16,p=0.050, respectively). The initial entry type into each tunnel was not significantly different within or between the closed and open-ended tunnels (Table 3.2) and there was also no significant difference between any of the diameters or end types in regard to furthest entry made by stoats (Table 3.2).

The 50 mm and 150 mm tunnels both had a similar mean number of entries for each end type, however the open 100 mm tunnel had more entries than the closed 100 mm tunnel ($F_{1, 19}$= 1.04, p<0.05). There was a strong trend towards fewer body entries in the closed 50 mm tunnels ($F_{1, 19}$=3.64, p=0.072), and fewer head entries into the open 50 mm tunnels (t_{17}=1.96, p=0.067). Stoats made more partial body entries into the closed 50 mm tunnels than the open 50 mm tunnels (t_{15}=2.74, p=0.015). There were significantly more body entries into the open 100 mm tunnel than the closed 100 mm tunnel ($F_{1, 19}$=4.9, p=0.039), but no differences between other entry types. Open and closed 150 mm tunnels had similar numbers of all entry types. Total entries declined over both three night testing periods ($F_{1, 61}$=7.1, p=0.01), but recovered between each experiment (Figure 3.2). The number of body entries into closed-ended tunnels declined significantly over the three nights ($F_{1, 32}$ =5.88, p = 0.21). Body entries into open-ended tunnels were not affected by night. There was no significant difference in the total number of entries made by male and female stoats (t_{64}=0.34,p=0.74).

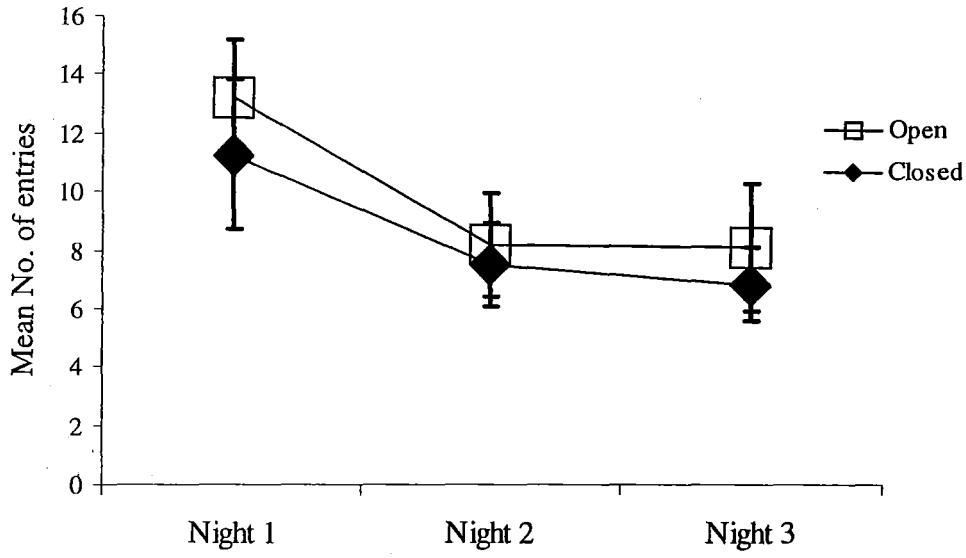

Figure 3.2 Total mean entries (± 1 S.E.) per night compared between Experiments 1 and 2 (Closed n = 12, Open n = 10).

In most cases the frequency of investigative activities did not differ between the different tunnel types, except that the closed-ended tunnels were sniffed more often than open-ended ones at all three diameters (Table 3.2)($p < 0.02$, 21d.f.). The open-ended 100 mm tunnel was climbed on significantly more often than the closed-ended 100 mm tunnel ($F_{1, 21}=6.67$, $p=0.01$). There were more approaches to the 150 mm closed-ended tunnel than the 150 mm open-ended tunnel ($F_{1, 21}=4.46$, $p=0.04$) or any other tunnel type.

Where possible stoats will exit a tunnel headfirst. Stoats leaving 100 mm and 150 mm open-ended tunnels were less likely to exit through the end they had entered than in the 100 mm and 150 mm closed-ended tunnels (100 mm - $t_{19}=3.41$, $p = 0.003$; 150 mm- $t_{14} = 2.65$, $p =0.019$). Stoats exiting 50 mm tunnels reversed less frequently from open-ended tunnels than from closed-ended ones ($t_{14}=3.02$, $p=0.009$).

3.4 Discussion

3.4.1 Entry behaviour

Willingness to enter a tunnel and preference for that tunnel type can be seen as two separate issues as an animals' preference for one tunnel may not preclude it being willing to enter another. Spurr and Hough (1994) demonstrated this in a limited way by comparing stoat entry behaviour into wooden and aluminium trapping tunnels. They found that although stoats may be more likely to enter the wooden tunnels first, they were equally willing to enter either tunnel type. While there are some considerable variations in repeated entry behaviour within the closed-ended tunnel types and between the open and closed-ended tunnels, there is no significant difference between any of the tunnels in the initial entry response and furthest entry made. Although body entries did comprise a greater proportion of initial entries into the open-ended tunnels it may have been due to the stoats prior experience with the closed-ended tunnels.

If one entry of sufficient depth is all that is required to kill the animal then repeat entry preferences may not be that important from a trapping perspective. The assumption is made that by showing continued interest in an object the animal prefers it to an object that it spends less time investigating or interacting with. During experiments 1 and 2, stoats made a similar number of repeat entries into all of the tunnel types with the exception of the closed-ended 100 mm tunnel. However, the closed-ended tunnels were investigated more frequently. Therefore the results do not provide any evidence for a strong preference for a particular tunnel design amongst the group as a whole. Individual stoats did interact with some tunnel designs more frequently than others.

Although the closed ended 100 mm tunnel had the lowest average repeated entries it was only one of two tunnel types that all stoats made a full body entry into, which was most likely to occur on the first or second entry into the tunnel. If a kill trap had been

placed in the tunnel, and required a full body entry to trigger the kill device, then it would have been more successful than other tunnel designs that had more repeat entries.

The closed-ended 50 mm and 150 mm had a similar number of total average entries per night, however there was a large amount of variation between the proportion of different entry types that comprise that total. The majority of entries in to the 150 mm tunnel were full body, in comparison the 50 mm tunnel showed a similar proportion of head, partial and full body entries. The 50 mm tunnel appeared to create a source of interest, presumably because the closed end and smaller diameter made it difficult to determine if anything was present in the tunnel without at least partially entering it. The same properties gave rise to the need for caution by the stoats, as approaching stoats could not be certain what they were entering.

Conversely, the 150 mm tunnel was far more open and could therefore be safely investigated without entry into the tunnel. Despite this, stoats would often enter, and some spent several minutes inside investigating the tunnel, only to return later and reinvestigate it. In some cases it may have been viewed as an alternate refuge as food items were brought in to the tunnels on several occasions. Additionally, stoats were able to move freely inside the larger tunnel.

The closed-ended 100 mm tunnel showed a similar pattern of entry types to the 150 mm tunnel. In both cases body entries made up the largest proportion of entries, the major difference being that 100 mm tunnels had a lower mean rate of repeated entry than all other tunnel types (open-ended tunnels included). The lower repeated entries may have been in part a function of the tunnel's size, as 100 mm the tunnel was large enough to be investigated without fully entering, so may not have held the same investigative appeal of the 50 mm diameter tunnel. Stoats were able to turn and move far more freely than in the 50 mm tunnel also but the conditions were still cramped in comparison to the 150 mm tunnel so they were not encouraged to stay in there for extended periods.

Stoats showed similar entry behaviour to all open-ended tunnels. Removing the end caps increased light levels and allowed the stoats to move through the tunnels rather than forcing them to reverse or turn to exit. The increased visibility in the tunnels may have made the stoats more confident to enter the tunnels as the interior was visible. It is also possible that the experience gained from experiment 1 increased the stoats' confidence around the tunnels.

End type affects both the initial and repeat entry behaviours of stoats entering tunnels. Previous field based trials found no difference in capture rates between single entry and run through tunnels (Dilks *et al.*, 1996; Maxwell *et al.*, 1997) and it is unlikely that this study would have found any differences in capture rate if the tunnels had contained traps. However, stoats interacting with the 150 mm tunnels were more likely to enter the open tunnel on any given approach and their initial entry was more frequently a body entry, even though each entry type was performed with similar frequency in both tunnels.

For the two smaller tunnels, end type had a more pronounced effect on entry behaviour. In the 50 mm tunnels there was the same chance of a stoat entering either tunnel type during any particular approach. However, the proportions of each entry type performed by the animals into each tunnel type were very different. The higher proportion of body entries into the open tunnel may have been due to increased light levels within the tunnel or the ability to move forward in a confined space.

Stoats made significantly fewer body entries into the 100 mm closed tunnel than the open 100 mm tunnel, however body entries made up a similar proportion of the total entries in both tunnels. This suggests that while end type does not influence the likelihood of a stoat entering a tunnel, or the type of entry, it does affect their repeat entry behaviour in 100 mm tunnels. In addition, the closed 100 mm tunnel had a smaller standard error than all other tunnel types, which indicates that there was less variation in individual stoat's responses to the tunnel.

3.4.2 Exploratory behaviour

Habituation effects were demonstrated during each of the trials but this did not appear to have any effect on the subsequent trial in terms of diminished interest from the stoats. The experience of experiment 1 could have affected the outcome of experiment 2 in one of two ways. Either the stoat would have paid little attention to the tunnels as they had established that the tunnels did not contain any food (which was not the out come) or stoats continue to interact with the tunnels at similar levels to the first experiment. The later scenario was observed and in the case of the smaller two tunnels stoats performed more body entries in them. During the course of each night the animals generally spent less time smelling the tunnel before each entry, although they would still approach and smell the tunnel without actually entering it.

Bait was not used in the tunnels because it may have artificially increased interest in the tunnels as the stoats learned to associate the tunnels with a 'free meal' and masked any effect the tunnel variables had on entry behaviour. Conversely, this may also confound results because generally the primary motivation to search an object such as a tunnel is to look for food (Barnett, 1988). Any investigation by stoats would have revealed that the tunnels contained no food. However, as stoats continued to interact with the tunnels after their initial exploration, subsequent investigations may then be attributed to play behaviour in some circumstances. Another possible explanation for the continued interest is that stoats may have been checking the tunnels regularly to see if the 'prey' had returned.

Stoats were observed on several occasions to interact with the tunnels in what appeared to be more as a source of amusement, or to play rather than to investigate them. The white fur of the stoat's underbelly was clearly visible as they rolled about trying to wiggle into the tunnel. They were also seen to rebound off the side of the tunnel during particularly high-energy activity periods. They were very determined to get into the tunnels, as it was a tight fit for some of the larger males, yet they went to some lengths to gain entry.

3.4.3 Tunnel design

Different tunnel diameters and end types elicit various responses from stoats, thus the optimal tunnel diameter is dependent on the response required from the animal. If the requirement was for an animal to enter a tunnel and then stay there; i.e. if consuming a bait, then a large (>100 mm) tunnel would be the most appropriate size. Stoats were observed taking their food items into both the closed and open 150 mm tunnel and feeding on several occasions.

Trapping tunnels have several functions to perform and in addition to this kill traps place certain requirements on tunnel design. To select an appropriate diameter for a trapping tunnel it's purpose, the kill trap requirements and the animals' behaviour toward the tunnel all need to be taken into account. All the stoats in these experiments successfully entered every tunnel type on numerous occasions. They would probably all have been killed by a head set mechanism and a kill trap set further back would have killed most.

As only one entry is required for a kill trap to be effective, tunnels with more repeat entries or a higher proportion of body entries are not necessarily required. However, as repeat entries may indicate a preference for that tunnel type, the design used might be the difference between getting one more stoat in the field. Depending on the species being protected and the amount of damage any individual stoat may inflict, this could result in significant benefits for species survival. Therefore, any tunnel design which stoats demonstrate a preference for over others should be used to maximise the number of stoats it is likely to capture.

Efficacy of kill traps diminishes with increasing tunnel size because animals have more room to avoid the trap. This increases the likelihood of wounding rather than killing the animal, as the optimal kill zone is more difficult to target. This makes the trap set-up less humane and therefore less suitable to be used with a kill trap. Larger tunnels may also allow a stoat to enter a tunnel but avoid the triggering mechanism. This is one of the primary reasons why most trapping tunnels are equipped with two Fenn traps because

stoats will often avoid the first trap but become caught in the second (Martin, 1997; Speed, 1997).

Excluding non-target species to protect them from injury and limit the level of trap interference they cause is the most important purpose of a trapping tunnel. The number of target species at risk from a kill trap is often inversely proportional to the size of the tunnel entrance. Smaller tunnels allow fewer non-target species to gain access to a trap; alternatively, larger tunnels require excluders to achieve the same goal. Some species, such as hedgehogs maybe able to fit through very small entrances if the area on the other side is sufficiently large (C. Berry, pers. comm.). In this situation a tunnel that maintained a smaller diameter may be more effective at excluding non-target species than one which opened out after the entrance.

Stoats can trigger a Fenn trap from either side. The proposed kill trap requires entry to be restricted to one direction only. Therefore, open tunnels are unsuitable for use with it because they provide more than one access point. An animal that encounters the trap from an unintended direction may either fail to set the trap off or be incorrectly positioned and be injured but not killed. However by encouraging the stoat to move through the tunnel they are more likely to trigger the trap.

3.5 Conclusions

Diameter does affect stoat entry behaviour (both entry type and frequency) into closed-ended tunnels but not into open-ended tunnels. End type affects both initial and repeat entry behaviour in all tunnel types, although it is more noticeable in tunnels with a smaller diameter. Both visibility within a tunnel and ease of movement may be important factors in a stoats willingness to re-enter a tunnel. Stoats prefer to exit a tunnel head first if possible. Stoats become habituated to tunnels through repeated exposure, which may affect entry type on subsequent nights.

Stoats were equally likely to enter and perform a body entry into any of the diameters at least once during a 12h period. Therefore, the 50 mm diameter was chosen as the most suitable diameter to continue testing (see next Chapter) because it had a high rate of repeat entries, it could exclude the greatest range of non target species and allowed little lateral movement from a stoat once in the tunnel, which enables a more accurate kill zone to be determined.

As the position of the trigger is yet to be determined the depth of entry required from a stoat to trigger the trap is unknown. A better knowledge of the depth to which stoats are willing to enter a 50 mm tunnel was needed. Due to trap requirements an open tunnel is not satisfactory, but as it encouraged a higher proportion of body entries than the closed-ended tunnel an end type that encourages a similar number of body entries but restricts entries to one end would be useful.

CHAPTER FOUR

Evaluating the effect of tunnel length on stoat entry behaviour

4.1 Introduction

Currently, most trapping and tracking tunnels used in either control operations or tunnel design trials are 600 mm in length (King and Edgar, 1977; King *et al.*, 1994b; Dilks *et al.*, 1996; Montague, 2000). This is considered the minimum acceptable length to house two Fenn traps and exclude non-target species. It also allows sufficient length for animals to leave tracks in a tracking tunnel (Murphy *et al.*, 2000). Based on the results of experiments 1 and 2 (see Chapter 3) it was decided to concentrate on the responses of stoats to different length tunnels with a 50 mm diameter. The possible effect of tunnel length on the entry behaviour of stoats has not been studied in any sized tunnel.

The length to which a stoat will enter a tunnel can have a major influence on trap placement within a tunnel and possibly the type of triggering mechanism used (I. Domigan, pers. comm.). Current kill traps require stoats to fully enter the tunnel and contact the trap directly. Placing traps further into a tunnel can reduce the number of non-target species at risk of injury. However, stoats must move further into the tunnel to make contact with the trap. It is not known how far they would be willing to move once in a tunnel, especially if the tunnel diameter restricts movement.

The choice of a suitable tunnel length for use in the field thus requires a trade off between two different aspects of tunnel design. The first is that the tunnels need to be a practical length to use in the field. As tunnel length increases, so does handling difficulty and the number a trapper can carry per pack load decreases. Nevertheless, the tunnel must be long enough to fulfil its purposes of excluding non-target species and protecting the trap from interference or weathering (King and Edgar, 1977; Warburton, 1997).

Murphy *et al.* (2000) investigated the suitability of the standard tracking tunnel length currently in use (540 mm base and 615 mm cover) and concluded that it was an appropriate length to ensure that animals entering the tunnel would encounter inkpads and leave prints. In addition, observations from trapping operations found that double-trap tunnels (600mm) caught proportionally more animals than single-trap tunnels (300mm) and Martin (1997) suggested that this maybe a function of length. However, it is likely that it was improved bait condition rather than tunnel length that was affecting trap catch rate. Neither of these studies investigated the effect of tunnel length on stoat behaviour.

Mesh is often used on tunnel ends to exclude non-target species (King *et al.*, 1994b). It allows smaller target species to enter the tunnel and still gives the tunnel a more open appearance to an approaching animal than a solid end would. The capture rate of single entrance and run-through tunnels have been compared in several field trials, but the end type used in each case is not specified (Dilks *et al.*, 1996; Maxwell *et al.*, 1997; Speed, 1997). It is likely that both mesh or solid ends would have been used in these trials.

The primary aim of this experiment was to investigate the influence (if any) of tunnel length on stoat entry behaviour into 50mm diameter tunnels. A secondary aim was to investigate why the smaller open-ended tunnels had higher mean body entries than their closed ended counterpart (Chapter 3). To test this, mesh was tested as an end cap. Mesh increased the light level inside the tunnel but restricted entry to a single point – the aim of this aspect of the experiment was to determine whether open-ended tunnels had higher body entries because the stoats were able to move through them or because it was easier to see inside them.

4.2 Methods

Three tunnel lengths (400 mm, 600 mm and 800 mm) were tested. Based on the findings from experiments 1 and 2 a width of 50mm was selected for this experiment, because it was the diameter that fulfilled the majority of the trap requirements and stoats had

demonstrated they were willing to enter that diameter. The 400 mm length was included in this experiment to allow comparison of the results with those from the previous two experiments. It is also considered the minimum acceptable length to exclude most non-target species. The 800 mm length was used as the maximum practical length in the field. 600 mm is the standard length of many conventional trapping tunnels in use today.

The tunnels were constructed out of 'Iplex Novadrain' PVC and were off-white in colour (this change was due to discontinuation of the pipe used in previous experiments). The ends were capped with wire mesh (9 mm^2), secured by duct tape. Stoats had moved the tunnels frequently in previous trials, so a wire hoop was used to secure tunnels to the ground.

A motion sensor (obtained from 'visitor warning frogs' purchased from 'The Warehouse') was inserted 50mm from the end of the tunnel to establish whether or not the animals were proceeding to the end of the tunnels after they disappeared into the tunnel, which was out of camera view. The sensor was not visible from inside the tunnel and could only be triggered by a stoat passing in front of it while in the tunnel. The sensor was attached to a red light emitting diode (LED), which flashed when the sensor was triggered. It was visible from the observation area and detectable on the video. The battery unit for the sensor was housed in a small plastic container, which was buried in a hole next to the tunnel. The sensor was tested before and after each trial to ensure that it was still functioning.

The initial entry type, furthest entry made and investigative behaviours were analysed using a one-way ANOVA, as described previously (Chapter 3). The repeat entry data from this trial were analysed using linear regression.

4.3 Results

4.3.1 First encounter responses

Three individual animals (i.e. 25% of the study group) did not enter any of the tunnels during their respective three night testing periods. The remaining stoats made an entry on 19% of their first encounters with a tunnel. Forty two percent of stoats never entered the 400 mm tunnel, and 33% never entered either the 600 mm or 800 mm tunnels (Table 4.1).

Table 4.1 Counts of the first response of stoats upon initial encounter with each tunnel length.

Entry Response	Length (mm)		
	400	600	800
No Encounter	2	0	3
No Entry	8	9	7
Partial Head	0	1	0
Head	0	1	1
Partial Body	0	0	0
Body	2	1	1

4.3.2 Repeat entry responses

Over the 3-night trial periods, stoats entered the 800 mm tunnels on 32.8% (±7.6%) of approaches, the 600 mm on 29.5% (±8.8%) of approaches and the 400 mm on 23.4% (±6.9%) of approaches. There was no significant difference between the three lengths in the approach: entry ratio ($F_{2, 35} = 0.37$, $p = 0.69$), nor were there any significant differences found between the three lengths for either initial entry type or furthest point reached (Table 4.2). The sensor was triggered four times, twice by the same stoat in the 800 mm tunnel and once each by two different stoats in the 600 mm tunnels.

Table 4.2 The mean scores for initial entry type and the furthest entry made (n = 12). A higher score indicates more body entries.

Tunnel Length (mm)	Mean Ranks (± 1 S.E.) Initial Entry	Furthest point
800	2.41 (0.54)	2.50 (0.55)
600	1.91 (0.51)	2.33 (0.52)
400	1.67 (0.49)	1.83 (0.51)

A trend of more total entries with increasing tunnel length was evident, but not statistically significant ($F_{2, 35} = 1.57$, $p = 0.22$)(Figure 4.1). This trend was also reflected in body entries, with stoats being less likely to make a body entry into the 400 mm tunnel either on the initial entry or at any point during the night than the 600 or 800 mm tunnels. The other three entry types showed no particular trend at the different lengths.

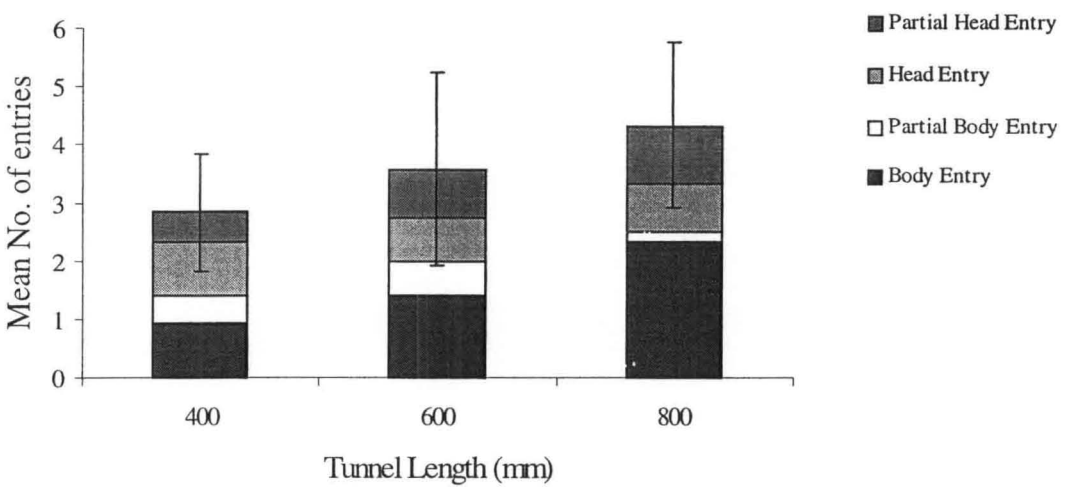

Figure 4.1 Comparison of the cumulative mean entries per tunnel type, with proportion of each entry type shown. (n = 12).

There was no significant difference in total entry rate between sexes ($t_{30} = 0.42$, $p = 0.68$) nor between experimentally experienced and naïve stoats ($t_{30} = 0.32$, $p = 0.75$). Other investigative behaviours were unaffected by tunnel length (Table 4.3). The number of entries per night declined over the testing period but not significantly ($p = 0.308$).

Table 4.3 Mean number of investigative behaviours performed towards each tunnel type (± 1 S.E.) (n = 12).

Tunnel Length (mm)	Behaviour		
	Approach	Smell	Climb
400	5.83 (1.52)	7.41 (2.28)	4.08 (2.15)
600	6.75 (1.03)	8.91 (1.81)	3.16 (1.02)
800	5.83 (1.61)	10.91 (3.50)	3.33 (1.21)

4.3.3 Responses to closed, open and mesh ends

Comparisons between closed, open and mesh-ended 400 mm-length, 50 mm diameter tunnels, revealed differences in entry rate and type (Figure 4.2). A high proportion of initial encounters resulted in entries in the closed and open tunnels (75% and 90% respectively) compared with the mesh tunnel (16%) (Two-tailed Fishers Exact Test, both $p<0.001$). The percentage of approaches that resulted in entries differed significantly between the three end types ($F_{2, 33}=5.48$, $p=0.009$). For both the open and closed tunnels approximately 50% of approaches resulted in entries compared to 23.4% in the mesh-ended tunnel.

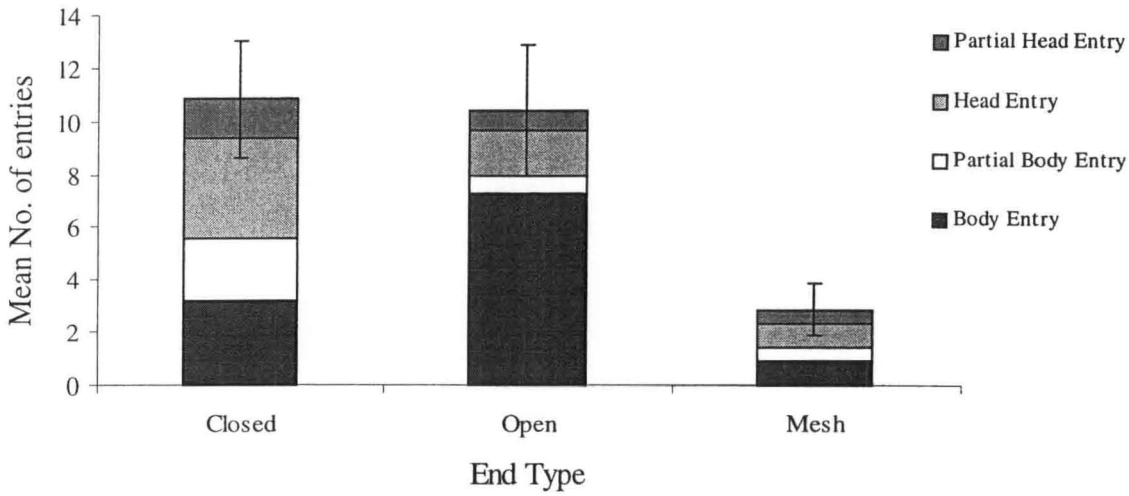

Figure 4.2 Comparison of the cumulative mean entries per tunnel type, with proportion of each entry type shown, of the three end types used in Experiments 1,2 and 3 (Closed and Mesh n = 12, Open n = 10)

The closed and open-ended tunnels had 54% more entries than the 400mm mesh-ended tunnel. The seven stoats exposed to all three end types made significantly fewer entries in the 400 mm mesh-ended tunnels than either closed ($t_6 = -2.42$, $p = 0.05$) or open tunnels ($t_6 = -2.87$, $p = 0.02$). Closed tunnels had significantly more head entries than mesh tunnels ($F_{2, 31}=4.17$, $p=0.026$) and significantly more partial body entries than either the open or mesh tunnels ($F_{2, 31}=5.72$, $p<0.001$). There were significantly more body entries into open-ended tunnels than into mesh tunnels ($F_{2, 31}=5.78$, $p<0.001$). Across all three trials body entries were, on average, the most common entry type, and occurred significantly more often than partial head or partial body entries ($F_{3, 135}=6.09$, $p<0.001$).

The 400 mm mesh tunnel had a significantly lower mean rank score than either the 50 mm or 100 mm open tunnels (from experiment 2) for initial entry type ($F_{8, 101}=3.56$, $p<0.00$). The 400 mm mesh tunnel also had a significantly lower score for furthest entry made than all of the open and closed tunnels ($F_{8, 101}=5.94$, $p<0.001$).

4.4 Discussion

4.4.1 Encounter and entry rates

Overall, interest and entries were much lower for this trial than what had been observed in the previous two trials. Although the initial encounter time was similar to experiments 1 and 2, stoats had fewer interactive periods with the tunnel in this experiment. All stoats approached and investigated at least one tunnel during their three night testing period, however some stoats did not interact with some tunnels. This was markedly different from the previous two trials where every stoat interacted with, and entered every tunnel. Five stoats performed body entries into only one diameter. Three of the stoats only made a body entry into the tunnel they were presented with on the first night, while the other two animals only fully entered the tunnel they had on the last night.

Several factors, such as different pipe colour, different end type, presence of a motion sensor, tunnel shyness and season may have influenced the low encounter rate. Neophobia towards the tunnels is one possible hypothesis to explain the low encounter rates. Three of the five new stoats used in this experiment did not enter any tunnel during their testing period, which would suggest that they might have been wary of tunnels generally. However, several of the stoats that had been used in experiments 1 and 2 (all of these individuals had entered every tunnel presented during these experiments), also refused to enter tunnels on one or more nights. This suggests that the animals' reluctance to enter may have been due to tunnel design variables particular to this trial rather than a general neophobic response toward tunnels.

The proximity to the start of the breeding season is another possible explanation for the low encounter rate. All six of the females (and several of the males) were transferred to the captive breeding programme immediately after completing this trial. Although there was no difference found between male and female entry behaviour it is possible that the proximity to the start of the breeding season may have affected the group collectively.

However this is unlikely as males become more active during the breeding season (Erlinge and Sandell, 1986) (Sandell, 1986) so if season had had an affect then it's most likely outcome would be increased activity from the male stoats, which was not observed.

4.4.2 Influence of tunnel length

The stoats' behavioural responses to the varying tunnel lengths were not statistically significantly different for any of the aspects examined. There was however, a trend for the number of interactions to increase with longer tunnels. The differences in total repeat entries were attributable to an increase in the number of body entries performed as tunnel length increased. It is possible that approaching stoats were unable to satisfactorily investigate the interior of the longer tunnels without entering. Therefore, they may have entered the longer tunnels more frequently to satisfy their curiosity, which is similar to the behaviour observed in the 50 mm closed tunnel during experiment 1.

4.4.3 Entry behaviour

It was necessary, especially at the longer lengths, to determine how far into the tunnel stoats were moving. Once the stoat had fully entered the 600 and 800 mm tunnels the observer had no way of knowing how far it would proceed into the tunnel. This information is relevant for appropriate placement of a trigger for the proposed kill device. The average length of a stoat (including tail) is 390 mm (male) and 347 mm (female) (King, 1990), so in the 400 mm tunnels once the animals tail had disappeared it could be reasonably assumed that the animal was within 50 mm of the tunnel end and in most cases closer. In the previous two experiments stoats that performed body entries fully entered the tunnels so their tails were no longer visible, but in most cases during this trial stoats' tails were still visible during a body entry, particularly in the 400 mm tunnels. However, even on the occasions when stoats did fully enter the 400 mm tunnel the sensor was not activated. This suggests that stoats were able to keep their body fairly compact while in the

tunnel, because if fully extended it would have been difficult for the males at least, not to trigger the motion sensor.

As tunnel length increases so does the distance the animals has to travel in a relatively confined space. Therefore for an animal to travel down a tunnel to its far end, it might perceive that there maybe something of interest (i.e. food) there. This provides one possible explanation for the increased number of body entries into the 600 and 800 mm tunnels. Stoats may have been unable to determine if the longer tunnels contained anything of interest without a closer inspection, so a body entry was necessary. The sensor was only triggered four times thus it could be assumed that most animals that entered the tunnels were not proceeding to the very end of the tunnel. This may have been due to the difficulty in moving that distance in a confined area or the stoats may not have needed to continue to the end of the tunnel to determine that there was no food reward. The addition of a bend in the tunnel may have stimualted further investigation, as the animals would be unable to investigate the tunnel without fulling entering it.

The sensor appeared to be a great source of interest to investigating stoats. The animals would often spend a larger proportion of their time spent around the outside of the tunnel exploring the motion sensor attached to the tunnel (in some cases this resulted in the sensor being knocked out from the tunnel) or most frequently the hole in which the battery unit was placed. Individuals would often remove the dirt and grass clippings used to camouflage the unit and attempt to remove it or dig on one side to get underneath it. The addition of a motion sensor may have detracted from the tunnels as a source of interest, as it provided a novel stimulus to those animals that had been used previously and gave new animals another object to investigate.

It appeared that the curiosity towards the tunnels displayed by stoats in earlier trials was refocused toward the motion sensor unit. Stoats often hunt prey that burrow (King, 1989a), and in the pens have been observed to dig tunnels themselves in patches of disturbed ground. The hole for the battery unit may have appeared a more likely prey

refuge once the stoats had established that there was nothing of interest in the tunnels. In hindsight the disruption caused by the addition of a sensor was not worth the limited amount of data it provided. However as there was no previous data available on how far into a tunnel the stoat would move it was a valid question to test.

4.4.4 Influence of end type

This experiment was in part confounded by the addition of a new end type, which may have affected entry behaviour. When the entry behaviour of stoats exposed to all three end types is compared, some significant variations are evident. Stoats were much more likely to actually enter an open or closed tunnel when they approached it and there were more repeat entries into these tunnel types than into the mesh-ended tunnel.

Mesh is commonly used in the construction of stoat traps to exclude non-target species, however the trapping tunnels are always much larger than the 50 mm piping used in this experiment. The results from experiments 1 and 2 suggest that the effect of end type varies with diameter, so it is possible that mesh may discourage entries into smaller tunnels but have less effect in larger tunnels.

It would have been interesting to repeat this experiment with the other tunnel diameters and with either the open or closed-ended types to better compare the three trials. This may have provided a clearer picture on the effect of length without the confounding elements of a new end type and motion sensor. I believe it is quite likely that increasing the length of larger diameter tunnels would have yielded similar results (i.e. more body entries into the longer tunnels).

For a stoat to repeatedly enter a tunnel it must either engage the stoats' curiosity, provide a source of amusement or provide a refuge. The 400 mm mesh tunnel was unable to provide any of these things. The mesh end allowed sufficient visibility inside the tunnel to give it little curiosity value yet stoats were unable to move through it so the tunnel appeared not to have little appeal as a play object. In addition the small size made it less

suitable for a refuge. Due to the low level of interest shown in these tunnels compared to the previous two experiments it is difficult to identify whether visibility inside the tunnel or the ability to move through the tunnel contributed to the higher proportion of body entries into open 50 mm tunnels. The longer tunnels had more body entries even though the increased length may have decrease visibility inside the tunnels, but even the 800 mm tunnel still had fewer repeat entries than the 50 mm open tunnel.

4.5 Conclusions

As several factors may have contributed to the low encounter rate observed in this trial it is difficult to draw any strong conclusions about the effect of length on entry behaviour from the results of this experiment. It appears that longer tunnels may encourage more body entries, at least in 50 mm diameter tunnels, and that disturbance around a tunnel may detract from the tunnel itself. It also appears that mesh may discourage entries into smaller tunnels. Stoats appear unlikely to continue to the end of a tunnel if it contains nothing of interest. Therefore curiosity maybe an important factor in stimulating stoats to investigate tunnels.

CHAPTER FIVE

Development of a hair collection method

5.1 Introduction

An aim of this study was to determine whether stoats would enter the tunnels developed during the previous pen experiments in the field. Consequently, a sampling technique was required that allowed any species that entered the tunnel to be identified. Setting a kill trap in the tunnel is an obvious way to achieve this, but the kill trap the tunnel is being designed for (see Chapter 1) was still a prototype, and was not available to be tested. None of currently available kill traps are suitable for use with these small-diameter trapping tunnels, so non-invasive sampling methods were investigated.

Bait take is not a suitable method, because the tunnels do not exclude other small mammals likely to be present in the same area, such as rats or mice, nor other animals capable of removing bait, such as insects. Footprint tracking was considered unsuitable for two reasons; firstly the tunnels are circular whereas this method requires a flat base for the ink and paper. Secondly the size of the tunnels means that stoats cannot walk in the tunnels, they are forced to crawl so clear footprints would have been difficult to obtain. It was decided that hair trapping would satisfy all criteria.

In addition to assisting with this tunnel design study, hair trapping was considered a potentially useful technique by Landcare Research, who were seeking to establish a non-invasive method of collecting DNA samples from stoats in the field. Non-invasive sampling techniques are often limited by cost and their inability to identify individual animals. By identifying individuals using these collection methods, Landcare Research aims to more accurately estimate the actual density of stoats in an area using the number of

recaptures to estimate absolute abundance. Consequently, assessing the usefulness of hair trapping for DNA sampling was incorporated as a secondary aim of this experiment.

Hair trapping is an increasingly popular, non-invasive sampling technique, because it reduces the stress caused to wild animals through live trapping and handling, but can still provide a substantial amount of information about individuals and populations (Valderrama *et al.*, 1999; Sloane *et al.*, 2000). It is a particularly useful technique when studying rare, elusive or trap shy species (Suckling, 1978; Scotts and Craig, 1988). Hair collected in traps is either identified microscopically, which provides information on species present in the area, or DNA is extracted from follicles and used to identify individuals within a population (Valderrama *et al.*, 1999; Sloane *et al.*, 2000).

Methods of hair extraction differ depending on the study animal and type of research. Valderrama *et al.* (1999) outlined several novel methods for gathering samples from both wild and captive animals. These included shooting a projectile covered with duct tape at the animal, baiting an enclosure constructed out of duct tape, covering food or feeding containers with tape and attaching double sided tape to a stick and touching the animal with it (captive animals only).

More conventional methods include suspending double-sided tape across burrow entrances (Sloane *et al.*, 2000) or using hair tubes containing sticky wafers or double sided tape (Suckling, 1978; Scotts and Craig, 1988). In larger species, e.g. Grizzly bears (*Ursus arctos*), barbed wire placed around bait stations has been used successfully to collect hair samples (Blair, 2001). In Britain, a coiled spring that snags hair samples from pine martins (*Martes martes)* was successful in pen and field trials (Messenger and Birks, 2000).

Hair has been collected from tunnels previously, using a hair tube technique developed in Australia to detect the presence of arboreal mammals (Suckling, 1978). Hair was collected on a strip of 'Permacel' double-sided tape that ran the length of the tunnels' ceiling. Later designs attempted to resolve the problem of bait removal after the first animal encountered a tunnel (Scotts and Craig, 1988) and were adapted for detecting

ground dwelling mammals as well. The hair was collected using double-sided tape attached to three sides of each end of the tunnel. Attempts have been made to sample stoats using hair tubes with double sided tape but these proved unsuccessful, although other animals were recorded during that study (Sleeman, 1987).

For DNA sampling, a collection method is required that removes hair with the follicle intact. Some of the unsuccessful options considered included double-sided tape, strapping tape, Velcro and bulldog clips. The option finally decided on was 'Trapper Glue'; a commercially available mouse or insect trap, consisting of an adhesive gum spread on sheets of cardboard. This product provided a suitable hair collection method and the cardboard backing made handling the substance easier in the lab and field.

The main objective of this trial was to test the effectiveness of three different hair removal techniques and assess their suitability for use in the field. Ease of application, removal, storage and the quality of the hair samples from each method were also assessed.

5.2 Methods

Seven male stoats were used for the pen trial, as that was all that were available at that time. All of the animals had been involved in at least one other tunnel trial and two of the animals were used in both the pilot and main hair collection trial. The video equipment, tunnel rotation schedule and general animal husbandry remained identical to the previous pen trials, except that in the second trial the stoats regular rations were reduced and substituted with the meat bait provided in the tunnels.

The tunnels were 400mm in length, 50mm in diameter and closed at one end with a plastic cap. They were constructed with 'KeyPlas' plastic piping. Although results from experiment 3 suggest that longer tunnels may encourage more body entries, the affect of length was not strong enough to warrant the extra expense and effort that accompanied the longer tunnels. During this trial, all the tunnels were baited with pieces of veal ('Jimbo's

pet food' brand). One piece was placed just behind the hair trap and the other was placed at the end of the tunnel to monitor the stoat's progress once it had entered the tunnel. The tunnels were baited to more accurately mimic the proposed field trial conditions and to try and encourage entry into the tunnels, although this had not been a problem in the previous trials.

A pilot study, using three stoats, compared a commercially available hair trap tunnel, the 'Faunatech Universal hair trap funnel' (referred to as the funnel in this chapter), with the tape method as described below, in open and closed tunnels. The funnel was 90 mm at its highest point and 25 mm at the deepest. The hair was collected on a removable wafer covered in 'Faunagoo', which was easily installed and collected. Data on one animal were lost because of video malfunction, but this was rectified before the next group of trials.

The main study used six stoats and tested three different methods of hair removal. The first method involved cutting a 10 mm wide strip from a 'Trapper glue' glue sheet and cutting it in half. Double-sided tape was then applied to the backing card of each piece and the two halves were stuck inside the tunnel approximately 50 mm from the entrance (Plate 5.1).

The second method involved coating a portion of a rubberband (Esselte Rubberbands-Size No: 62) with the 'Trapper glue', which was then placed in a slit in the tunnel, 50 mm from the entrance. The glue was scraped off the backing card and transferred to the rubberband using a small flathead screwdriver. The rubberband cut through the top third of the tunnel, which meant a stoat could not make a partial body or body entry into the tunnel without contacting the rubberband.

The third method was based on the same idea but employed a flap rather than a rubberband. A 15mm wide strip from a sheet of trapper glue was folded in half with each end refolded to form a base. The plastic coating was then removed from the middle section of the strip to expose the sticky surface. This portion was inserted into the tunnel through a

slit, which had been cut in to the pipe 50mm from its end. Once the flap was inserted, the two end flaps were held flat against the tunnel using rubberbands. These three methods are referred to as the tape, band and flap methods in this and subsequent chapters.

The tunnels were close-ended to force the stoat to exit the tunnel by reversing. This increased the chances of removing follicles as the adhesive substrate contacts against the lay of the hair, so there is less chance of only newly shed hair being picked up. Shed hair is sufficient for microscopic analysis for species identification but is insufficient for DNA analysis to identify individuals, because there is no follicle present (D. Gleeson pers. comm.).

Once the tunnels had been removed from the pens each day, the hair traps were removed and examined for the presence of hair. All samples were initially stored in snaplock bags and those that contained hairs were later examined under a dissecting microscope to check for the presence of follicles. These samples were not used for DNA analysis, but samples collected for analysis should be stored in ethanol or in a freezer (-4°C). The tunnels were cleaned daily but gloves were not used when handling them because of the difficulties of working with this type of glue while wearing gloves. Direct contact with the tunnels was restricted to essential work only and they were handled through a plastic bag as much as possible. Each stoat was checked, while in their nest box, at the conclusion of the trial to ensure there were no obvious signs of damage from hair being removed.

The effects of hair collection methods on entry type, total entries, visits per night and investigative behaviour were analysed using a one-way ANOVA.

5.3 Results

5.3.1 Pilot trial

The pilot trial, which involved the Faunatech Universal hair trap funnel, gathered only one hair sample from the closed-ended tunnel. All three stoats were observed to interact and make at least a head entry into the funnel, but no hair was collected. No bait was removed from the open tunnel or the funnel and only one piece was removed from the closed-ended tunnel on the first night. All three stoats attempted an entry on their first encounter with the open tunnel, two entered the funnel on their first encounter and one stoat entered the closed-ended tunnel on the first encounter. Tunnel type had no significant effect on repeat entry rates, although when entry types were compared there were significantly more head and partial head entries than body or partial body entries ($F_{3, 35} = 3.56$, $p = 0.025$). The entry rate declined over the testing period, but this was not statistically significant ($p = 0.12$).

5.3.2 Main trial – Initial and repeat entry behaviour

In the main study, all three of the hair collection methods successfully collected large numbers of hairs with follicles, sufficient to be useful for DNA analysis (Plate 5.1). Landcare Research required a minimum of 3 hairs (with follicles) for DNA analysis and all samples contained at least 20 hairs with follicles. Hair samples were obtained from three of the six stoats involved in the trial.

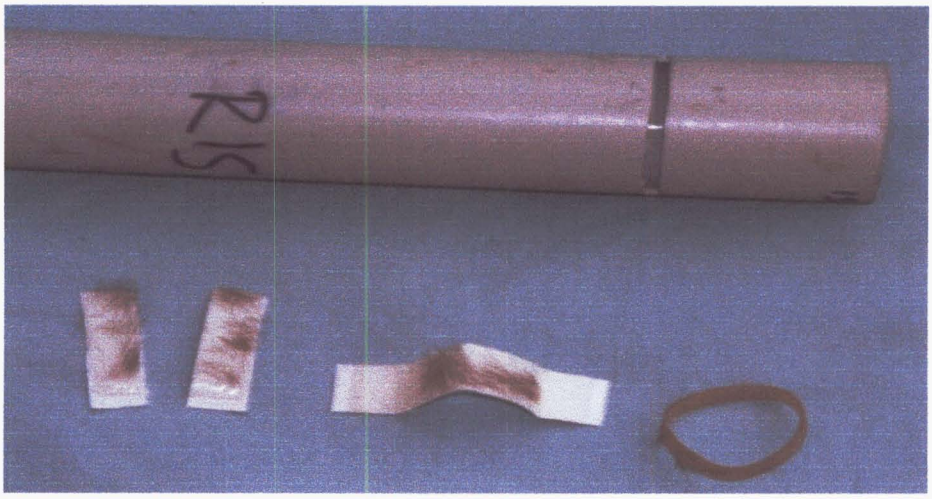

Plate 5.1 The three hair collection methods trialed (from left, Tabs, Flap and Rubberband), 50 mm tunnel with Flap or rubberband slit in background.

Stoats made an entry attempt on 50% of first encounters with all hair collection methods. All of these entries were head or partial head entries. The percentage of approaches that resulted in an entry into tunnels containing a flap; band or tape were 41%, 37% and 30% respectively. The flap method had the highest number of repeat entries but this was not significantly different from the other two collection methods ($p = 0.8$). There were significantly more head entries than either body or partial body entries for all three trap types ($F_{3, 71} = 5.08$, $p = 0.003$). The number of entries declined on the final night but this was not significant ($p = 0.8$).

Mean total entries per night for each trap type were similar to the closed-ended 50 mm tunnel trialed in experiment 1 ($p = 0.95$) (Figure 5.1). The proportion of each entry type did not differ significantly between the tunnels with hair traps and the one without, although there was a trend for more head entries into the tunnel containing hair traps. A higher percentage of approaches resulted in entries into the closed-ended 50 mm tunnel (Experiment 1, Chapter 3) than into any of the tunnels containing hair traps, but it was not statistically significant.

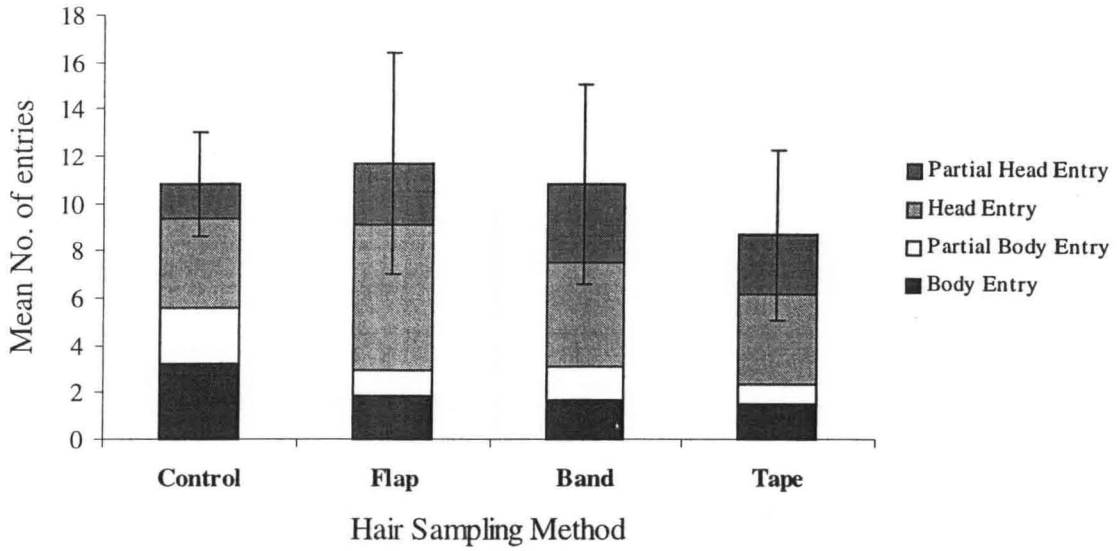

Figure 5.1 Comparison of the cumulative mean entries per tunnel type, with proportion of each entry type shown, of the three hair collection methods compared with cumulative mean entries of a control (50 mm closed-ended tunnel - Experiment 1) (Control n = 12, Flap, Band and Mesh n = 6).

Stoats approached and smelled the tunnels more frequently on the first night than on the two subsequent nights, but they were more likely to climb on the tunnels on the second night. The type of hair collection method used did not affect the investigate behaviours of the stoats. However, of the six stoats tested in the main study, only three entered the tunnels far enough to leave hair and remove bait. This variation in entrance behaviour was significantly different between individuals ($F_{5, 17}$=25.2, p< 0.001). There was also a significant level of variation between individuals in all three investigative categories (Approach: $F_{2, 17}$=6.4, p=0.004, Smell: $F_{2, 17}$=5.3, p=0.008 and Climb: $F_{2, 17}$=3.3, p=0.041).

5.4 Discussion

5.4.1 Entry behaviour

With such a small sample size, it is difficult to draw any robust conclusions, but the data available do indicate that the presence of any kind of hair collection method may act as a deterrent to some stoats. The three animals that did not fully enter any of the tunnels in this trial had all entered 50 mm tunnels in previous trials. This suggests that it was an effect of the hair collection methods in the tunnel, not the tunnel type itself.

Entry behaviour did not differ significantly between tunnels that contained hair traps and the 50 mm closed-ended tunnel used in experiment 1 (Chapter 3). However, if similar responses (i.e. 50% of animals' only making head entries) were observed in a larger study group then some significant differences maybe detectable.

It is possible that the visual stimulus presented by each collection method affected the stoats' entry behaviour. The flap method particularly would have presented a highly visible barrier to approaching animals, while the tape would have been barely visible. The three animals that did fully enter the tunnels showed no significant variation in entrance behaviour in response to the different collection methods. All animals performed more head and partial head entries than other entry types, which would indicate that the presence of the hair traps made them weary of fully entering the tunnels.

There was a dichotomy in terms of the number of total entries performed and general investigative behaviour between the three stoats that left hair samples and the three that did not. The three stoats that did fully enter the tunnels consistently investigated and entered the tunnel more frequently. The exception to this was the stoat that entered a closed tunnel in the pilot trial but did not enter any of the other tunnels in the pilot trial or main trial where it was also used. The two stoats that were used in both sets of hair collection

trials did not perform a body entry into any of the tunnels during either trial with the exception outlined above.

Although hairs were pulled out from the root only one obviously adverse reaction was observed. This was from a stoat exiting a tunnel containing a flap. The animal moved backwards quickly then appeared to become stuck and moved forcefully from side to side as it was exiting, moving the tunnel considerably from it's original position. However, within 30 seconds the animal returned to the tunnel, spent some time investigating the tunnel by smelling it and then proceeded to fully enter it again. The stoat did not produce such a dramatic display during its next exit, nor on the three subsequent body entries it made that night. None of the other animals that entered the tunnels exhibited responses that were particularly different from those shown by stoats exiting tunnels in previous experiments.

5.4.2 The effect of baiting

The addition of meat baits to the tunnel was intended to further encourage entry into the tunnels. As the main aim of this study was to test the suitability of the hair traps, and not tunnel design, previous disadvantages of using bait were now considered advantages. It also resembled the field situation more closely, where bait is usually placed in every tunnel. For the stoats that consistently made body entries into the tunnels, the addition of baits almost doubled their mean number of entries per night compared to the mean entry rate of the 50mm closed tunnel used in experiment 1. However, adding bait did not assist in getting all the stoats to enter. The effectiveness of the bait may have been compromised because the animals were still receiving daily food rations. Meat baits may prove a better incentive in field trials as it is unlikely that wild stoats would be as well fed as their captive counterparts.

Previous studies have found that the addition of meat baits will increase tracking rates and trap catch (King and Edgar, 1977; Murphy *et al.*, 2000). Unlike previous trials,

entries did not significantly decline over the three night testing period. This implies that the stoats continued to return to the tunnels because they were rewarded for their exploration with food. The three previous experiments found that the presence of bait was not necessary to lure stoats into tunnels, and the results of this study suggest that baiting may not provide a sufficient entry incentive for animals that are reluctant to enter tunnels. Therefore, while the presence of bait is useful as a lure to attract the stoat to the tunnel, tunnel design may have a larger influence on the likelihood of the stoat actually entering the tunnel once there. A tunnel that appeals to a stoats curiosity maybe more likely to be investigated.

5.4.3 Suitability of hair collection methods

The main factors used to assess the suitability of the hair collection methods were ease with which each method could be installed into, and removed from the tunnel, the quality of the hair samples obtained by each method and any affect the method may have on the animals entrance behaviour. All three methods were effective in removing sufficient quantities of hair containing follicles and all three could be used in a field situation. However, the flap and rubberband methods were both easier to install and remove from the tunnels than the tape method. There was a much greater risk of contaminating the glue with the tape method. Of the three, the flap gave the best hair sample, in terms of quantity but required more glue sheets and produced more waste. The rubberbands provided fewer hairs but were easier to remove from the plastic bags when being examined later.

The inability of the Faunatech Universal hair trap funnel to capture any hair was predominately due to the large entrance of the tunnel and the reluctance of the three test animals to enter it completely. It is possible that because the funnel was so short and open in appearance the stoats were not stimulated to investigate it. Results from the length experiment (Chapter 4) indicate that longer tunnel may encourage more body entries and the funnel was only 200 mm in length, half the size of the tunnels used for the other hair

sampling methods. Initial field trials involving the funnel, found that while it was effective at collecting hair from some species, it did not detect the broad range of species it was designed to (Lindenmayer *et al.*, 1999). Lindenmayer *et al.* (1999) suggested that the strong odour of the wafer used in the funnel might deter some species. If this is the case then it is possible that the odour of the glue used in this experiment could have also discouraged entries.

A range of tunnel sizes may be necessary to detect multiple species (Suckling, 1978; Scotts and Craig, 1988; Lindenmayer *et al.*, 1999), however, in this experiment stoats were the only species of interest and therefore tunnel dimensions could be specific to them. Hair tubes used in previous studies have been of a similar diameter to the ones used in this study but normally slightly shorter (Suckling, 1978; Sleeman, 1987; Scotts and Craig, 1988).

Hair traps are being used more regularly to sample species diversity and gather DNA information as an alternative to more invasive sampling techniques (Lindenmayer *et al.*, 1999; Sloane *et al.*, 2000). They are inexpensive to construct, so a wide area can be sampled and they do not have to be checked daily, thus reducing labour costs. However, this study (and others) has found that they may not be an effective sampling technique for all individuals within a species (Sleeman, 1987; Lindenmayer *et al.*, 1999; Messenger and Birks, 2000). Despite this, the methods tested in this study have the potential to provide valuable information if the problems with the collection methods discouraging some stoats from entering can be resolved.

5.5 Conclusions

The three methods trialed all successfully collected adequate hair samples for both microscopic and DNA analysis. The Faunatech Universal hair trap funnel is not suitable to collect stoat hair samples because of its large entrance. The flap or rubberband methods are more convenient to use than the tape method. Stoats' willing to enter a tunnel containing a hair trap did not alter their entry responses with different hair traps. However, the presence of a glue based hair collection method discouraged some stoats from performing body entries into tunnels, therefore reducing their chances of being detected by hair sampling. The use of meat bait may not be sufficient to entice reluctant animals to enter a tunnel, but it does increase the entry rates of those stoats that will enter.

CHAPTER SIX

Trapping tunnel and hair collection method field trial

6.1 Introduction

The primary aim of this field trial was to validate the results gained in the previous pen trials (Chapters 3-5) and evaluate the chosen tunnel's suitability for use in the field. Field validation was sought because the behaviour of a captive population of animals is not necessarily a good indicator of the likely responses of wild animals to new stimuli. If captive individuals are repeatedly exposed to such stimuli they may become more adept at exploring new objects (Barnett, 1988). Also any avoidance behaviour observed in captive animals may be magnified in wild populations.

A secondary aim of the field trial was to determine if tunnel end type had any measurable affect on the frequency of entry in the field. The proposed kill trap design (see Chapter 1) requires entry to be restricted to one end only (Ian Domigan, pers. comm.). Closed ended tunnels encouraged far more entries in pen trials than mesh ended tunnels of similar dimensions did (Chapter 4), but the pen trial results (Chapter 3) also suggested that open ended tunnels encouraged more body entries. Previous field trials that compared capture success of closed and open tunnels found no difference (King and Edgar, 1977; Dilks *et al.*, 1996; Speed, 1997) but in my pen trials end type caused significant variations in initial and repeat entry behaviour. Because the tunnels used in the other studies were larger, it could not be assumed that stoats (*Mustela erminea*) would react similarly to the tunnels used in this trial.

Monitoring stoat populations is always fraught with difficulties and current methods, such as foot print tracking and trap catch, have both limitations and advantages (King and Edgar, 1977). One alternative being considered by Landcare Research is a monitoring system that uses hair to identify not only the species type but also the

individual by analysing DNA extracted from the hair follicle. During previous pen trials (detailed in Chapter 5) several successful hair sampling methods were developed for this purpose. Consequently, a further aim of this trial was to test the viability of at least one of the hair sampling methods in a field situation and assess the feasibility of using hair sampling as a monitoring technique for stoats.

As a monitoring and sampling tool, several studies have found that hair sampling is a useful addition to other methods such as scat analysis or live trapping (Suckling, 1978; Scotts and Craig, 1988; Lindenmayer *et al.*, 1999; Messenger and Birks, 2000). It is becoming an increasingly popular method of collecting DNA from species which are difficult to sample(Sloane *et al.*, 2000; Blair, 2001).

Stoats are monitored to confirm their presence in an area, detect changes in abundance, and determine the success of control operations (McDonald and Lariviere, 2000). However they are difficult to accurately monitor as stoats' are sparsely spread over large areas relative to their body size, their population size is highly variable, home range areas vary with changes in prey abundance and population density and not all animals are equally detectable with current monitoring methods (King, 1989a; McDonald and Lariviere, 2000). Long term monitoring programs using standardised techniques are at present the only way to counteract the enormous variability displayed by stoats in so many aspects of their ecology (King, 1994a).

The most common methods of monitoring stoat abundance in New Zealand are kill trapping and footprint tracking tunnels (King, 1994a; Gillies and Williams, 2000). Other methods include live trapping for mark recapture studies, or foot print tracking in areas with extended periods of snow cover (Messenger and Birks, 2000). Experienced field operators can also detect stoats in an area using field sign such as scats, runways or dens (King, 1994a).

Kill trapping is a destructive sampling technique that will alter the composition of the species being sampled, however if trapping is being used for control then it provides

additional information for no extra effort (King, 1994a). It may provide a biased sample as not all stoats are equally trappable and individual trappability varies with season, prey abundance and experience (Alterio *et al.*, 1999). It is also unsuitable to use as a post control monitoring method if the control operation was trap based, because it may fail to detect stoats which avoided traps during the control operation. However trapping does provided a known number of animals and it does allow the populations age structure to be studied (King, 1994a). Information obtained from trapping operations is used to calculate a density index, which is expressed as the number of stoats captured per 100 trap nights. This standardised index allows comparisons between areas and between years and seasons in the same area. It has been found to be a reliable relative index of ferret abundance (Cross *et al.*, 1998), but maybe less sensitive to fluctuations in stoat abundance (Alterio *et al.*, 1999).

Tracking tunnels are a non-destructive sampling method used to detect the presence of stoats and other small mammals in an area (Gillies and Williams, 2000). They can also provide an indication of changes in density over time by measuring the level of activity in an area (i.e. percentage of tunnels tracked). They are more cost effective than traps therefore can be used over larger areas, which is useful when trying to detect or monitor such an active and sparsely distributed species (Gillies and Williams, 2000). One of the major disadvantages of the tracking tunnel method is its inability to identify individual animals; as it is difficult to distinguish increases in population from increases in activity (King and Edgar, 1977). One animal could easily visit all stations on a line in one night, which may lead to assumptions of greater stoat density than actually present in the area (Gillies and Williams, 2000). In addition, tracking tunnels still have to contend with many of the same trappability issues that kill traps do (King and Edgar, 1977).

6.2 Methods

6.2.1 Study site

A field trial was conducted in the Nelson Lakes National Park from 2nd - 16th February 2001. The first site was at the head of Lake Rotoroa (41°56′S, 172°41′E) and the second in the Lake Rotoiti area. These areas are covered by beech forest with the predominant species being red beech (*Nothofagus fusca*), silver beech (*N.menziesii*) and mountain beech (*N.solandri var. cliffortiodes*). A mixed red and silver beech forest dominates the lower slopes, while mountain beech is more common at higher altitudes. The area also supports some small patches of podocarp, principally rimu (*Dacrydium cupressinum*) and southern rata (*Metrosideros umbellata*).

Stoat densities in beech forest have been estimated to range from 2 – 10 animals km^{-2} (Basse *et al.*, 1999) and are dependent on prey density (King, 1989a). During the period of this study relatively high stoat densities would be expected because the previous year had been a mast year and it coincided with juvenile dispersal. However stoat density varies markedly not only between years and seasons but also between areas. Stoat control is attempted within the Rotoiti Mainland Island using Fenn traps set out in a series of trap lines (Butler, 1998). The trap index from this area showed higher stoat densities during 2000/01 than in the previous two years of monitoring.

Kill trapping had also been used periodically between 1974 and 1995 to estimate stoat abundance at Mt. Misery (Wilson *et al.*, 1998). Captures per 100 trap nights ranged from 0 to 6 during the monitoring period. Tracking tunnels are run quarterly at both the Mainland Island and Mt. Misery (a non-treatment area for the mainland island) sites to estimate stoat density (Butler, 1998). Stoat densities in this area are likely to be comparable to other beech forest areas in the country (C. Gillies pers. comm.). The number of animals collected from the Nelson Lake's area for a national survey of stoats within the National parks was similar to many other areas sampled (King and Moody, 1982a).

6.2.2 Tunnel Specifications

The tunnels used were 400mm in length and 50mm in diameter. Although the length trials indicated that longer tunnels encouraged more entries; the 400mm tunnels from experiments 1 and 2 still had a higher number of entries than the 800mm tunnel from experiment 3. For this reason, and because shorter tunnels are easier to transport and handle in the field, the 400mm length was chosen over the other two trialed lengths. The 50mm diameter pipe continued to be used based on its ability to correctly orientate the stoat for a kill device, minimise risks to non-target species and its small size, which made it preferable for field use.

Open and closed-ended tunnels were alternated along each line. This method was employed instead of random allocation of tunnel types because it increased the likelihood of a stoat encountering the alternate trap type if it moved along a line. The closed-ended tunnels were blocked off at one end using masking tape, which was a much less time consuming method than the metal plates or plastic caps used previously in the pen trials and maintained a similar light level inside the tunnel. Each tunnel had a slit sawn at one or both open ends into which a sticky tab was placed for collecting hair samples. These slits were made slightly deeper for the second half of the trial to accommodate the rubberband hair collection method.

Based on the results of the pen trials (Chapter 5) the flap method of hair collection was chosen for the field trial. The flaps were strips of 'Trapper glue' sheets folded in half with each end refolded to form a base. The plastic coating was then removed from the middle section of the strip to expose the sticky surface. This portion was inserted into the tunnel through the slit cut into the pipe 50 mm from its end. Once the flap was inserted, the two end flaps were taped flat against the tunnel using duct tape. This had the added advantage of protecting both the bait and sticky part of the flap from the elements.

During the second half of the trial the 'flap' hair trap was replaced with the rubberband (Esselte Rubberbands - Size No: 62) hair trap that had also been previously

trialed in the pens. It was hoped that the reduced surface area of the band would decrease wasp interference, therefore increasing the likelihood that a stoat investigating the tunnel would enter rather than being deterred by the presence of wasps. This method involved coating a portion of a rubberband with the 'Trapper glue', which was then placed in a slit in the tunnel, 50 mm from the entrance. The glue was scraped off the backing card and transferred to the rubberband using a small flathead screwdriver.

6.2.3 Field placement

Each tunnel was staked down with a single metal hoop placed in the middle of the tunnel. Tunnels were placed a set distance apart, but when that point was reached placement was based on 'best site, best sign', normally within a 5m radius of the marked point. Most tunnels were placed beside logs, the base of a tree or clumps of reasonably dense undergrowth. These areas were identified as possible hunting locations or den sites for stoats.

All tunnels were checked daily throughout and rebaited if necessary. If the hair trap had hair or insects on it then it was replaced. For each trap the status of the bait and hair trap was recorded as well as noting any sign of interference with the tunnel. Interference was defined as any movement of the tunnel from its original position, removal of the stake, and any chewing or scratching damage to either the taped end of the tunnel, the flap, band or the tape which holds the flap in place. The number of wasps found on each hair trap was also recorded along with the presence of any other invertebrates found either attached to the hair trap or in the tunnel. The presence of insects on the hair traps was taken into account when constructing the index of stoat contacts per 100 trap nights. All hair samples collected in the field were removed from the tunnel and placed in snaplock bags while still attached to the hair trap. Back at the hut the hair was removed from the hair trap using forceps and placed in a vial. The hair samples collected at the Lake Rotoroa sites were placed in ethanol. The samples collected at the Lake Rotoiti sites were stored in vials in the

freezer (-4°C). Both these methods were recommended for preservation of hair follicle samples (D. Gleeson pers. comm.).

All tunnels in this trial were baited with two $1cm^2$ (approximate) pieces of fresh rabbit meat. Several studies have found that tracking and trapping rate are increased with the addition of meat baits (King and Edgar, 1977; Murphy *et al.*, 2000). In the open-ended tunnels the baits were placed 100 mm from each end of the tunnel. The closed-ended tunnels also had one bait placed 100 mm from the tunnel's entrance, the other was located at the closed end of the tunnel in an attempt to indicate whether or not animals which entered the tunnel proceeded down to its end. The bait was replaced as needed, in most cases this required at least half the tunnels to be rebaited every day.

Tunnels were set for four nights based on the recommendations from a tracking tunnel study by Murphy *et al* (2000). They found that tracking rates typically increased between nights two and four, decreasing again between nights four and six.

6.2.4 Rotoroa site layout

Mt Misery is positioned at the head of Lake Rotoroa and has the D'Urville and Sabine valleys on either side of it. Three lines were run, one at the base of Mt Misery and one in each of the adjacent valleys. The geography of the area meant that all the lines were quite isolated from each other. Nevertheless, it is possible that some stoats could have moved between the different lines during the course of the trial (Figure 6.1).

The first line was placed along the D'Urville valley track, and consisted of 10 tunnels placed approximately 200 m apart. The tunnels were placed 5 m to 10 m off the track, depending on gradient and wasp nest locations at each site. This line was originally planned to run for four nights but due to continued wasp interference was pulled out a day early.

The second and third lines were located at the base of Mt Misery along the D'Urville valley side. These consisted of 10 tunnels that ran parallel to each other at

approximately 100 m intervals. Those lines were originally intended to be part of a grid, but this was abandoned because of time constraints. These lines were also removed after three nights instead of four because of wasp interference.

The fourth line was placed up the Sabine valley track and again consisted of 10 tunnels placed approximately 200 m apart. The tunnels were placed approximately 10 m off the track. This line was run for all four nights but on the third night the flaps were substituted for the rubber-band hair collection method. The reason for this change was to try and decrease the number of wasps that were getting stuck in the flap hair traps.

6.2.5 Rotoiti site layout

The Lake Rotoiti sites were at Big Bush Forest (41° 47′ S, 172° 49′ E), the Rainbow valley(41° 53′ S, 172° 55′ E), the Rotoiti Nature Recovery project (a DOC Mainland Island)(41° 49′ S, 172° 51′ E) and the top of the Speargrass track (41° 50′ S, 172° 47′ E)(see Figures 6.2 and 6.3 for line locations). Unless otherwise stated the rubberband hair collection method, as described above and in Chapter 5, was used in all tunnels at this site.

Big Bush is an area of mixed silver and red beech forest located behind the St Arnaud township, with access from the Teetotal track (Plate 6.1). The density of stoats in a nearby area (Duckpond stream) was monitored using kill traps from 1990-95. During this time a maximum of two stoats per 100 trap nights was never exceeded (Wilson *et al.*, 1998). A 500 m x1000 m grid of tunnels was set up for four nights. Each line contained 10 tunnels at 100 m spacing and each of the five lines were 100 m apart. The lines ran parallel with the base of the hill and were laid out on a compass bearing of 290° using hip chains to measure the distance. All the tunnels were baited with two pieces of rabbit meat as described above for the first three nights of the trial, however due to wasps removing the bait one large piece of rabbit on the bone was used on the final night.

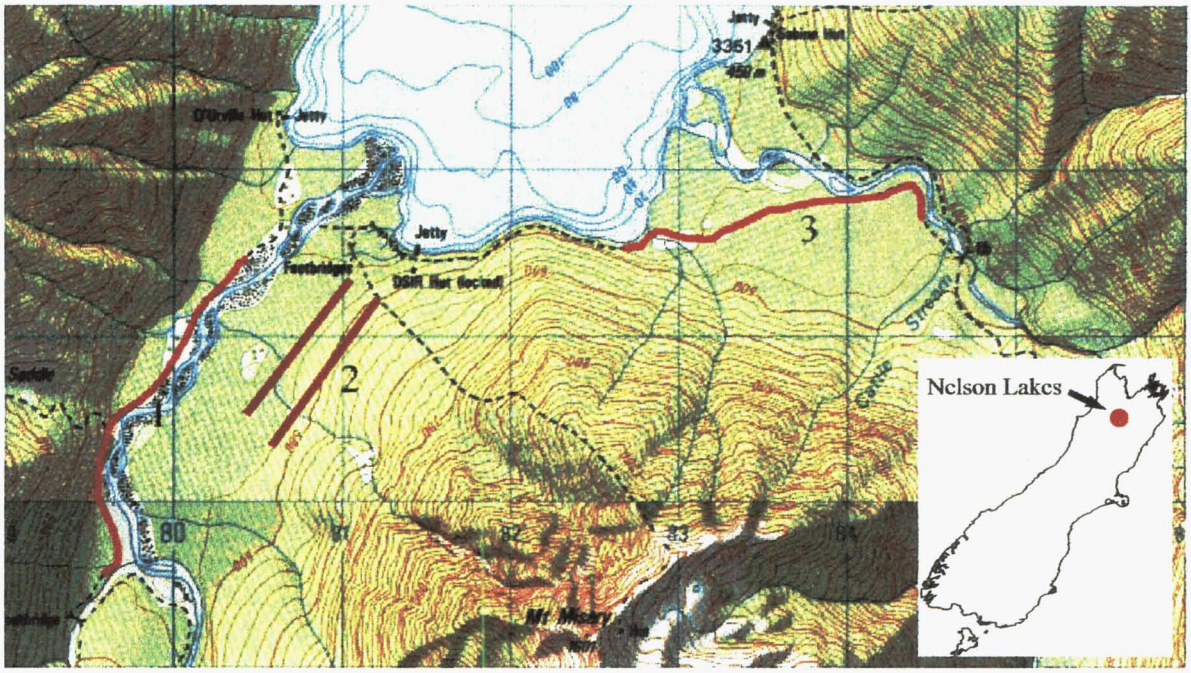

Figure 6.1 Location of Lake Rotoroa lines. **1**: D'Urville Valley, **2**: Mt. Misery & **3**: Sabine Valley.

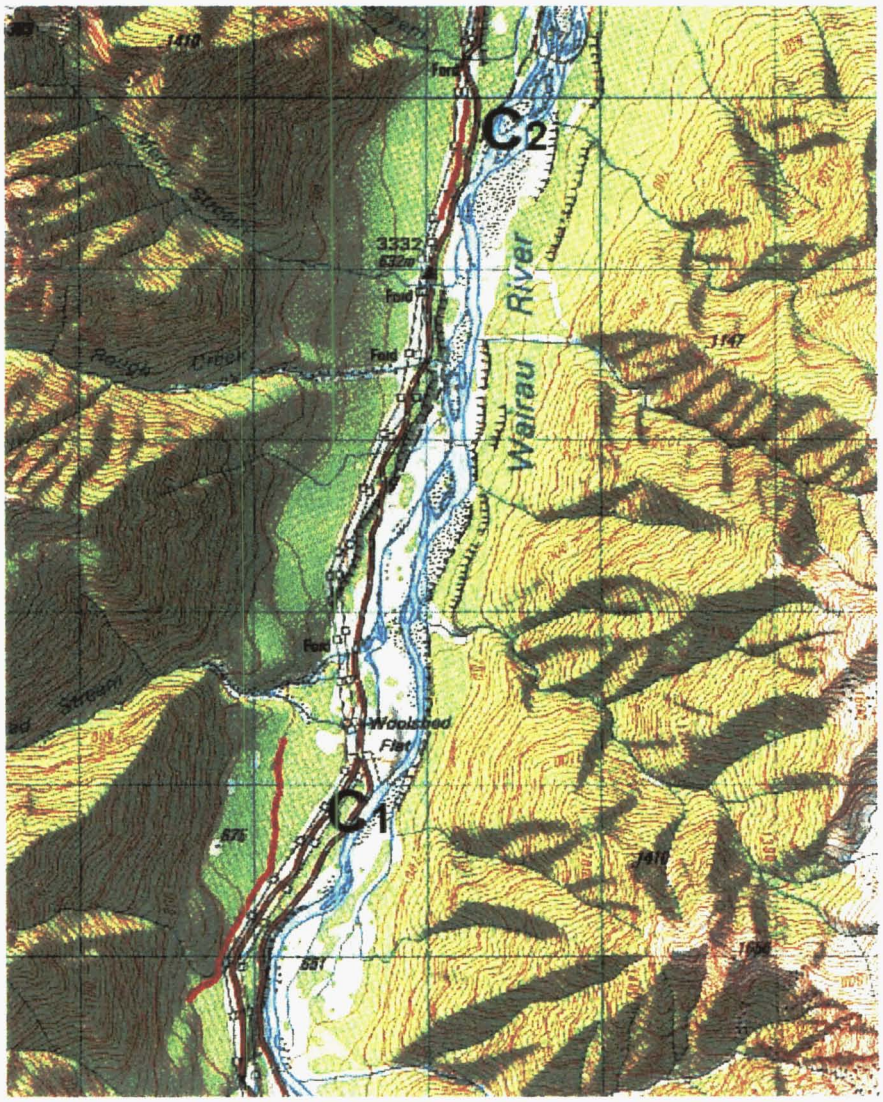

Figure 6.2 Location of Rainbow valley lines (part of Lake Rotoiti group). **C1**: Primary hair trap line, using rubberband method. **C2**: Secondary hair trap line, using flap method.

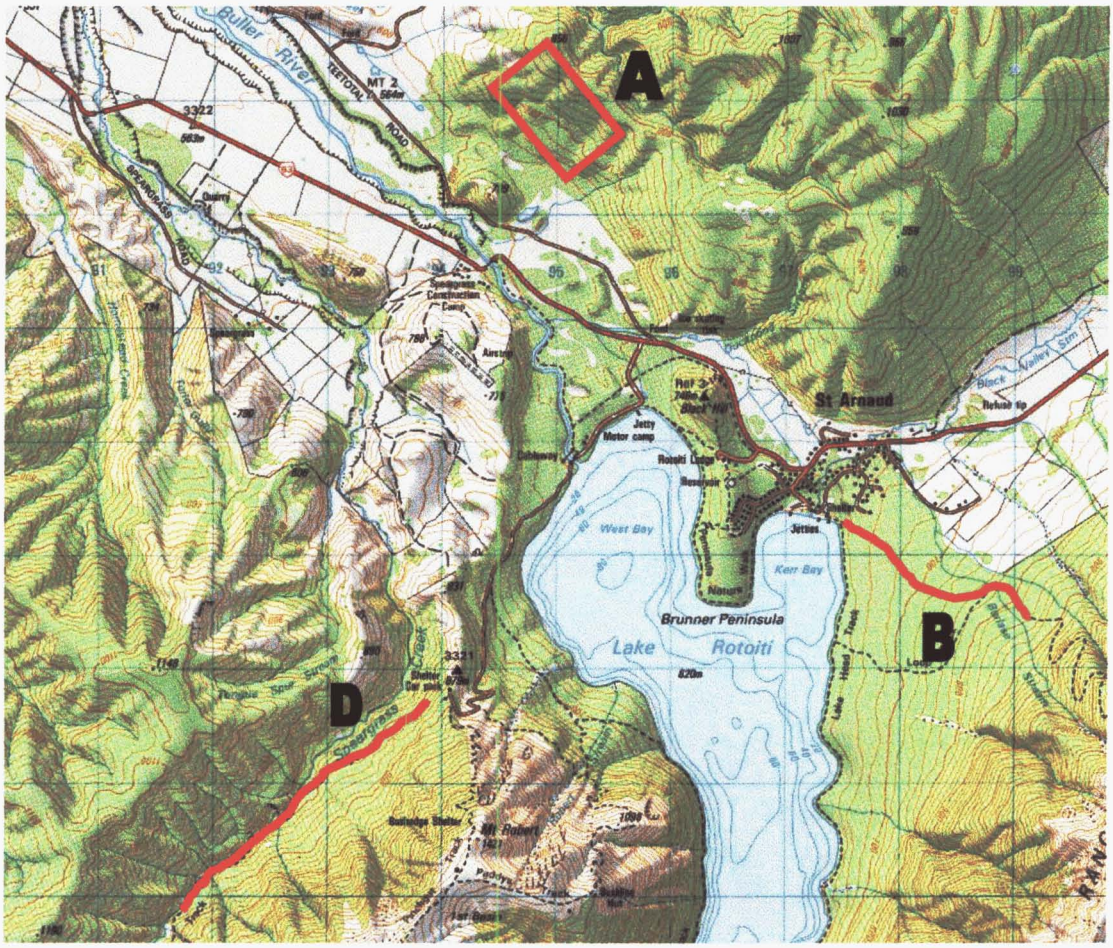

Figure 6.3 Location of Lake Rotoiti lines. **A**: Big Bush Forest (site of 1km x 500m grid), **B**: Rotoiti Mainland Island & **D**: Speargrass Track.

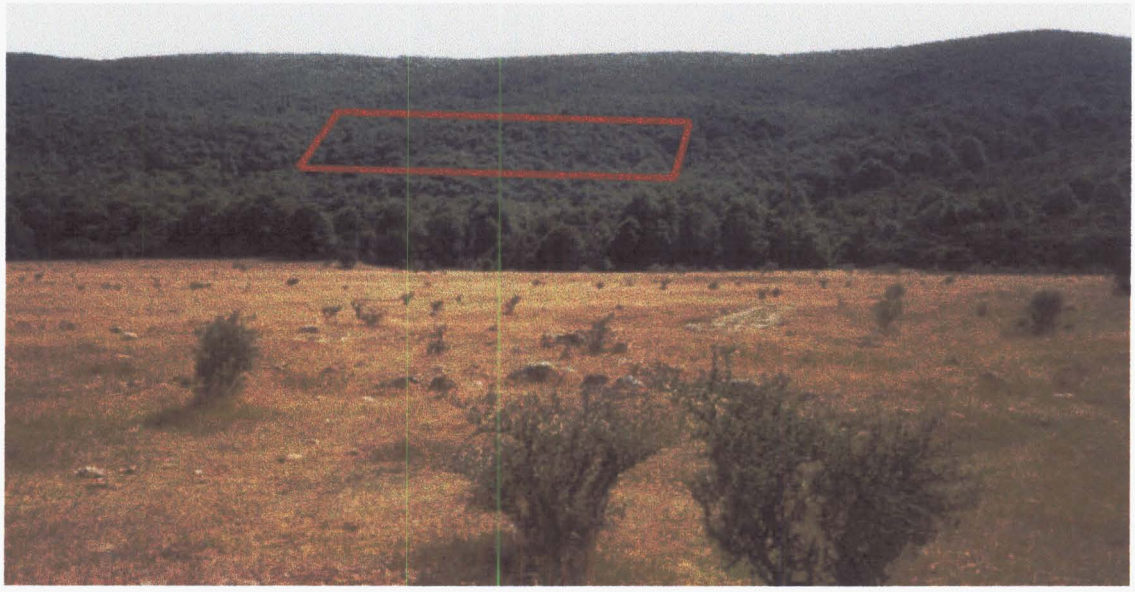

Plate 6.1 Big Bush Forest study area (approximate grid location outlined in red).

The Rotoiti Nature Recovery Project covers 800ha along the side of Lake Rotoiti and is one of DOC's Mainland Island projects. It runs from the lake edge up to the top of the St Arnaud range and encompasses five ridges. There has been intensive pest control carried out in this area for the last five years, including mustelid trapping. The area has been completely mapped out in a 100m x 100m grid. One line of 15 traps was placed along the Loop Track and start of the St Arnaud range track. Each trap was 100m apart and between 20 and 100m from the track. These tunnels were baited with brown hens' eggs rather than rabbit meat after continuing difficulties with wasps removing bait. The tunnels were set for four nights and checked daily.

The Rainbow Valley is situated to the east of the St Arnaud range. The Wairau River runs through it and the Wairau-Hamner Springs hydro road runs on the river's true left bank. The valley contains the main power lines connecting the North Island with the hydro electricity produced in the South Island. There is a 100 m farmland margin between the road and the bush edge to allow passage for the power lines. Fifteen tunnels were placed along the forest edge approximately 20 m in from the paddock/forest boundary. The understory of this section of forest was severely depleted due to the presence of stock. The tunnels were set 100m apart and baited with brown hens' eggs. Another six tunnels were placed out in cover that was located between the road and the pasture strip. They were baited with eggs but used the flap method instead of rubberbands to collect hair, as the wasp activity was lower in this area. This particular habitat was chosen in keeping with the 'best site, best sign' theory of trap placement because a live stoat was viewed running into the cover.

The Speargrass Track runs along the west side of the Mt Robert ridge. It has a fairly open forest understory. Fifteen tunnels were placed 20 m off the track at 100 m intervals. The first ten traps were put out on alternating sides of the track but the last five were placed on the right side only due to a miscommunication with field staff. The tunnels were run for three nights only due to time constraints and tunnel shortage. All tunnels were

baited with eggs and used the rubberband method. Another six traps were placed along the end of the line for the final two nights using flaps instead of bands in the tunnels.

6.2.6 Hair Analysis

The samples collected from the field trials were stored in a freezer (-4 C°) at Landcare Research Lincoln and examined using both low and high power microscopes. The hair samples were checked for follicles and I attempted to identify what species each sample belonged to by comparing them to samples collected from stored animals held by DOC (St Arnaud). Landcare Research (Lincoln) now holds those hair samples. This group of reference samples included hairs from a stoat, three rats (different pelt colours and summer and winter coats), a mouse and a possum. These species were thought to be the ones most likely to come into contact with the tunnels. Hair identification books (Adorjan and Kolenosky, 1969) (Brunner and Coman, 1974) were also consulted. The hair characteristics examined included the length and width of the hairs, banding and ridging patterns, colouring, and scale patterns.

Those hair samples that contained follicles and were identified as likely to have come from a stoat were sent for DNA analysis by Landcare Research Auckland. The DNA analysis was undertaken as a separate Landcare Research project and so was outside the scope of this study, however the results were made available to report in this thesis.

6.2.7 Stoats Abundance

An index of stoat abundance was calculated from the number of traps with stoat hair samples, by modifying the standard density index used during trapping operations as described by King (1994). Hair samples were considered a contact and treated in the same manner as a caught stoat or non-target species. Sprung traps included any tunnel where the hair trap had been sufficiently damaged to stop it collecting hair and any hair trap with wasps or other insects on it. As the effects of wasps in the trap could not be measured,

there are two densities reported for each trapping area. On the wasp-adjusted index any trap that had one or more wasps present on it was described as sprung but for the alternative index these traps are included in the untouched category. In some cases inclusion of wasps greatly reduced the number of trap nights available.

6.2.8 Statistical Analysis

The number of hair samples collected from open and closed tunnels for each species was compared using a two-tailed Fishers exact test.

6.3 Results

6.3.1 Hair identification

The field study confirmed that stoats would enter these narrow, tubular tunnels in the wild. Stoats and rats reacted differently to closed-ended tunnels (p=0.003) (Table 6.1). No rodent hair samples were obtained from closed-ended tunnels, whereas six of the nine stoat hair samples were collected from closed tunnels.

Of the eight samples sent away for DNA analysis, three were positively identified as coming from stoats. The three confirmed samples came from Mt Misery, Big Bush and Speargrass, and were all collected from closed-ended tunnels. The other five provided an insufficient amount of material for analysis to be carried out. Either the follicles weren't large enough or there weren't enough hairs in each sample (D, Gleeson pers. comm.). Both hair removal methods trialed did work in a field situation but may need some fine-tuning to provide higher quality hair samples.

In total 26 hair samples were collected but only 15 were identified. All of these were classed as either stoat or rodent samples (Table 6.1, columns 2-4). The other 11 were either unable to be identified or the identification was only tentative. Some of the samples are likely to be from possums due to the type of tunnel disturbance occasionally observed. Other samples may have come from contamination due to jersey fibres etc.

Table 6.1 Summary of Hair Sampling results for each trapping area. All averages are presented ± 1 S.E. where applicable. C = Closed-ended tunnels, O = Open-ended tunnels. +wasps = Hair traps with wasp attached included in disturbed tunnels, - wasps = Hair traps with wasps attached included in unsprung tunnels.

Site location	Total N° of hair samples collected	N° of stoat hair samples collected		N° of rodent hair samples collected		Mean nightly percentage of tunnels with bait removed		Mean percentage of nightly disturbance	Mean percentage of tunnels with wasp interference		Mean N° of wasps per tunnel		Contacts per 100 trap nights (+ wasps)	Contacts per 100 trap nights (- wasps)
		C	O	C	O	Nights 1-3	Night 4		Nights 1& 2	Nights 3 & 4	Nights 1& 2	Nights 3 & 4		
D'Urville Valley	1	0	0	0	0	73.3 (6.6)		20 (0)	80 (11.5)		7.8 (1.1)		0	0
Mt. Misery	4	1	1	0	0	81.6 (8.8)		20 (5.7)	85 (6.6)		5.9 (0.6)		6.06	3.63
Sabine Valley	3	1	0	0	2	70 (8.1)		17.5 (8.5)	95 (2.5)	15	8.95 (1.5)	1 (0)	4.44	3.45
Big Bush State Forest	8	1	2	0	4	85.2 (7.4)	12 (3.7)	5.5 (2.2)	31.6 (5.2)		1.3 (0.1)		2.55	2.04
Rainbow Valley	4	1	0	0	0	0		One case only	0	9.5 (4.8)	0	1 (0)	1.88	1.81
Rotoiti Mainland Island	2	0	0	0	0	0		One case only	0		0		0	0
Speargrass Valley	4	2	0	0	0	0		0	Only 1 wasp captured		0		3.67	3.64

6.3.2 Hair capture rates

The capture rate varied between the study areas quite markedly from 0 stoats /100 TN to 6.06 stoats /100 TN (+ wasps) (Table 6.1). The average capture rate over all areas where stoats were detected was 3.72 stoats / 100 TN (+ wasps) or 2.91 stoats / 100 TN (- wasps). In comparison the mean trap catch rate of the Rotoiti Mainland Island for the last three years was 0.17 stoats /100 TN. The inclusion of wasps as a source of disturbance markedly affected the capture index.

The tunnels that were baited with rabbit had a high rate of bait removal, except on the last night in the Big Bush grid when the portions were increased in size (Table 6.1). In many cases the bait may not have been completely removed but rebaiting was necessary due to insect damage. Common wasps (*Vespula vulgaras* (Linnaeus)) , ants (Formicidae) and maggots (Diptera) caused most of the damage. On the Rotoroa lines at least 70% of the tunnels where no bait or one bait was removed were closed ended. This trend was also evident in the Big Bush grid, where 59% of all tunnels with no or one bait removed were closed-ended. No eggs were removed or interfered with in any way when used as bait even though stoats were detected in tunnels, which contained them.

Disturbance rates were fairly low and in most cases the level of disturbance would not have prohibited hair collection. A few tunnels were removed from their stakes and moved away from their original sites or had the 'flaps' completely or partially removed. However most cases of disturbance consisted of the duct tape covering the tunnels end or holding the 'flap' down being chewed or scratched. Some of the tunnels were urinated or defecated on (species unknown), this was more prevalent at the Rotoroa sites.

Insect interference, particularly from the common wasp, may have a major impact on success, but this is dependent on the hair trap and bait type used as well as the time of year. The level of wasp interference varied markedly with both the hair trap and bait type used (Table 6.1). It was highest on those lines with flaps and rabbit bait and non-existent on lines that used rubberbands and eggs. On the Rotoroa lines wasp densities could reach

20 wasps per tunnel. In comparison at Big Bush the percentage of tunnels that captured wasps and wasp densities per tunnel was low but there was still high wasp activity in the area. Tunnels would often be cleared of bait within two hours. The larger portions of rabbit used on the final night were not as easily removed but this resulted in a higher level of continued interest in the tunnel the following day.

6.4 Discussion

This field trial has validated the pen trials' findings and confirmed that 50 mm tunnels are suitable for use in the field. Stoats were equally likely to enter either closed or open-ended tunnels and more likely to enter the closed tunnels than were rodents. This may be beneficial for designing hair trapping tunnels and kill traps, if the number of other species entering the tunnels can be reduced then hair identification is simplified and the kill traps are more target specific. However it could be argued that excluding other pest species may not be as desirable for a kill trap as rats particularly, could be considered a beneficial non target capture.

6.4.1 Hair identification

One of the limitations when trying to construct a capture index was that not all hair samples were able to be confirmed by DNA analysis so it is likely that more than one sample may have come from the same individual. As an example the two stoat samples collected from the Mt. Misery lines were collected from adjacent traps on successive nights. It is likely that this was the same individual but only one of the samples was confirmed as stoat hair from DNA analysis. Revisits by the same individual is the type of situation which DNA sampling is designed to correct for. This demonstrates that better quality hair samples are needed to justify the use of DNA analysis.

Also unlike a Fenn trap the capture of one individual does not preclude the capture of another. From the type of samples collected it seemed unlikely that more than one

animal had visited the traps between each check, however it is a possibility if the traps are left out in the field for extended periods between inspections. In this situation DNA analysis could be used to identify individuals once a database detailing individual markers had been established.

Chances of cross contamination in the field are slim using these collection methods and if contamination by another species (e.g. clumsy researcher) does occur then it will be easily identified during analysis. All samples were stored in individual containers but it is possible that samples could become mixed up during the initial identification or during DNA extraction. Good recording systems and laboratory skills should minimise the risk of either of these situations occurring.

6.4.2 Stoat densities

Predator trapping is carried out throughout the year in the Mainland Island. Permanent mustelid trap lines encircle the area and there are also two internal lines, giving a total of 300 traps. All tunnels are mesh ended (i.e. closed-ended) and contain a single Mark VI Fenn trap. The project has had an average trap catch rate of 0.17 / 100 TN over the last three years, however this figure has not been corrected for sprung traps or non target captures so is likely to be higher. This year it has increased to 0.32 stoats / 100 TN, almost twice as many animals have been caught this year as last year. During the period the hair trap tunnels were being run 6 stoats were caught in the Fenn trap lines, including three on one of the internal lines. However no hair samples were collected from my line run inside the Mainland Island. This suggests that hair traps may not be sensitive enough to be used as a monitoring tool in areas where control is ongoing or that they need to be spread over a wider area to detect mustelid activity.

The number of hair tunnels needed to detect stoats in an area is dependent on the size of the area being sampled and the proportion of that area used by stoats (Choquenot *et al.*, 2001). The likelihood of detection is also influenced by home range size, trap spacing and the probability of a stoat entering the tunnel once it has detected it (Brown and Miller,

1998). Choquenot et. al (2001) predict that over 200 tunnels would be needed to detect a population of 5 or less stoats in a 10 000 ha area. Brown and Miller (1998) suggest that to accurately monitor changes in stoat abundance over a large area either a high number of stations or frequent inspections are needed. Stoats were detected in five of the seven areas surveyed in this study and the density estimated from the hair trap index of those areas is higher than within the mainland island, if compared with their trap catch index. While the number of traps placed in each area was sufficient to detect the presence of stoats, multiple lines of at least 2km with traps spaced further apart (> 400m) would be needed to monitor a population within an area.

Stoat densities are determined by prey density (King, 1989a) and in most years beech forests are considered a marginal habitat for stoats (Murphy and Dowding, 1994). However in mast seeding years densities can reach 10 stoats km^{-2} (Basse *et al.*, 1999). Although there was no previous monitoring of stoat densities in some of the areas sampled, it is reasonable to assume that they would be similar to the densities recorded in the mainland island area and found in beech forests generally.

Several hair sampling surveys conducted in Australia found high rates of contact from possums (*Trichosurus vulpecula*), yet in this study I collected no confirmed possum samples. Lindenmayer et al. (1999) found that hair tubes were less effective at detecting Trichosurus sp. in areas of dense understory than more open forests, which may explain the low encounter rate. Alternatively the small entrance diameter may have successfully excluded possums from reaching the hair traps.

Of the methods tested, sticky rubberbands are the preferred hair trap method as they collect hair successfully, are the least visually intrusive and the least susceptible to insect interference. They are also the quickest of the three methods in terms of set up time required per tunnel. Rubberbands produce less waste than flaps (flaps need a plastic lining, duct tape and glue sheets) and are the least expensive method as one glue sheet can service approximately 100 rubberbands but only produces 8-10 flaps. One of the main drawbacks

of this method is that they may not retain their adhesive properties for the same length of time as the flap method. The glue can 'ball up' on a small portion of the band if not applied correctly, although it can be easily rectified by respreading or adding additional glue. This could affect the quality of the hair samples collected if the bands are left unchecked in the field for extended periods.

6.4.3 Influence of hair traps on stoat behaviour

Many of the hair samples collected comprised of only a few hairs, whereas the samples obtained from the pen trials yielded a substantial number, most of which had follicles. This suggests that the stoats which we obtained samples from in the field were not entering the tunnels fully. There are several possible reasons for this; firstly because of the high level of wasp interference in the tunnels the stoats may have been reluctant or unable to fully enter the tunnels. When the flap method was used the density of wasps collected indicated that they would provide an effective deterrent to stoats entering the tunnels. The rubberbands did not capture nearly so many wasps but there was still many which moved into the tunnel to feed or were active around it (pers. obs.).

Bait removal by wasps was in itself not so much of a problem as the pen trial demonstrated that stoats were quite willing to enter unbaited tunnels. However their continued presence inside the tunnel and propensity to get stuck on the hair traps was most likely the major influence on the likelihood of a stoat entering a tunnel. They also created an added hazard to researchers.

Secondly, the presence of the hair trap may have discouraged some stoats from making a body entry into the tunnel as was seen in the initial pen trial (Chapter 5). In the pen trials, animals were observed to bend their heads round the corner of the tunnel to investigate it while their bodies remained virtually parallel with the tunnel. If stoats were investigating the tunnels in this manner then they may contact the band briefly before pulling back, leaving a small hair sample. One way of overcoming the stoat's reluctance to

enter further is to move the hair trap closer to the entrance as this would increase the probability that stoats which investigated by head entry only would leave hair samples.

The odour of the trapper glue may also have made stoats more reluctant to enter the tunnels. Results from the pen trials (Chapter 5) suggest that the presence of any hair collection method may deter up to 50% of stoats from entering the tunnels. Researchers who trialed the Faunatech Universal hair trap funnel suggested that the odour of the wafer used to collect the hair may have deterred some species (Lindenmayer *et al.*, 1999). If chemical odours do deter some species from entering tunnels then duct tape may not be suitable to use as an end type material. Human odour may also have influenced stoat behaviour as gloves were not worn while handling the tunnels and they were handled daily during line monitoring.

6.4.4 The influences of trap type and bait on detection success

The increased surface area of the flaps make them more likely to trap insects than the rubberband method. Although they are designed to capture large crawling insects as well as mice the glue does not contain any insect attractants. The number of wasps captured by each hair sampling method differed dramatically. On the Speargrass Track and Rainbow Valley lines most or all of the wasps caught were caught on flaps which had been put out later as extra tunnels. The Sabine Track line had the highest densities of wasps per tunnel prior to a switch to rubberbands.

As bait, eggs are a far cleaner option (barring breakage's) than rabbit meat. They have a minimal preparation time, keep fairly well and attract less attention from wasps and other insects. In addition, the tunnel diameter makes it difficult for stoats to remove eggs. However they are fairly bulky to carry in the field and require far more care when handling. Rabbit is very easy to bait traps with and probably has more success as an attractant. If the meat is obtained directly from the carcass some preparation time is needed to skin and butcher the animal before cutting up the meat into appropriate sized pieces. It is easy to carry quite large amounts without taking up too much room, however, it does dry

out and is subject to insect damage to a far greater degree than eggs with many traps needing rebaiting daily. A decision on the appropriate bait type to use will be dependent on several factors such as availability of bait, length of time spent in the field, the storage facilities available, and wasp numbers in the area.

6.5 Conclusions

Stoats will enter both closed and open ended 50 mm tunnels in the wild. It seems that the use of a closed-ended tunnel may deter rodents from entering tunnels. Both flaps and rubberbands will successfully collect hair samples, however the quality is not always adequate for DNA analysis. The type of hair trap and bait used has a substantial influence on the amount of insect interference in the traps. In turn the level of insect interference, particularly wasps, may affect stoats' willingness or ability to enter tunnels. The corrected trap catch rate for the hair tunnels was higher than the trap catch rate from the Rotoiti Mainland Island in many sampled areas. This suggests that while there are still some technical issues to resolve, hair traps have the potential to become a useful non lethal sampling tool for monitoring of stoat populations.

CHAPTER SEVEN

General Discussion

7.1 Summary of the thesis

This thesis has examined the influence of several tunnel design variables on stoat entry behaviour and used this information to assist in designing a trapping tunnel for a new type of kill trap currently being developed.

Diameter does affect repeat entry type and frequency in closed ended tunnels, however, the comparison of tunnel diameters in open-ended tunnels demonstrated that on its own diameter may have a minor effect on stoat entry behaviour (Chapter 3). Diameter did not affect initial entry behaviour into any of the tunnel types and had no influence on the depth to which stoats entered the tunnels. Longer tunnels encouraged more body entries into 50 mm diameter tunnels (Chapter 4). However, it appears that stoats will not usually proceed down to the end of the tunnels at any length. End type affected both initial and repeat entry behaviour in all tunnel types, although it was more apparent in tunnels with a smaller diameter. Removing the end cap resulted in significant changes in repeat entry behaviour into the 50 and 100 mm tunnels. In addition, it appears that a mesh end type may discourage any type of entry into 50 mm tunnels. During field trials stoats were detected in both open and closed-ended tunnels, but more frequently in closed-ended tunnels (Chapter 6).

It appears that the interaction between diameter and end type has the greatest influence over stoat entry behaviour into tunnels. The interaction between diameter and end type was more apparent in the tunnels with a smaller diameter, but it also affected initial entry behaviour into the closed-ended 150 mm tunnel. In the smaller diameter tunnels, movement was more restricted, and solid ends reduce visibility. In addition, these experiments have shown that stoats prefer to exit head first from tunnels when given a

choice. These factors may not encourage repeated body entries once the tunnel has been investigated.

Based on the results of the pen trial, and requirements of the proposed kill trap, I believe the most suitable trapping tunnel design is a 50 mm diameter tunnel, at least 400 mm in length, with a solid end. The trap design requires entry to be restricted to one end only, so open ended tunnels, although preferable because of their higher proportion of initial body entries, are not suitable. In addition, stoats were far more willing to enter 50 mm tunnels with solid ends than mesh ends. Future work should focus on developing alternative end types. For example, a small metal cross at one end may be sufficient to restrict entry to one end, yet give a similar visual perception to an open tunnel.

The 50 mm tunnel has several advantages over the larger tunnels for trapping tunnel design. It has the potential to restrict a greater range of non-target species than larger tunnels, without the need for excluders. Its small size reduces the likelihood of stoats being able to avoid any triggering mechanism once they have entered the tunnel, and restricts their movement inside the tunnel, increasing the probability of a humane kill. Their compact size may lead to increased trapper efficiency, as larger and more remote areas can be covered by the same number of people and the initial set up time may be decreased.

The results of the length trial indicated that the number of repeat body entries may increase in longer tunnels. However, because of other confounding factors during that trial (discussed in Chapter 4) it is difficult to predict whether longer tunnels with alternative end types would actually result in a greater number of stoats being killed. Therefore 400 mm would be considered the minimum acceptable length for a 50 mm diameter trapping tunnel.

Use of a glue-based hair collection method may discourage some stoats from performing body entries into tunnels, thereby reducing their chances of being detected by hair sampling. However, the presence of a hair trap did not affect the entry behaviour of stoats that do fully enter the tunnels. The proportion of entry types performed did not differ

between closed-ended tunnels with or without a hair trap. Moving the hair trap closer to the tunnel entrance may increase the proportion of animals detected, because those stoats that restrict their investigation to head entries (three of the six stoats observed in the pens) would be more likely to contact the trap. The use of meat bait may not be sufficient to entice reluctant animals to enter a tunnel, although it does increase the repeat entry rate of stoats that will enter the tunnel and take bait.

The three hair collection methods developed all successfully collected adequate hair samples for both microscopic and DNA analysis during pen trials. However, samples collected during the field trials were, in six of nine cases, not of sufficient quality to extract DNA from and positive species identification was not always possible through microscope examination of the hair itself. The type of hair trap and bait used had a strong influence on the amount of insect interference in the traps. Stoats were detected in five of the seven areas sampled and an adjusted capture index for the hair tunnels was found to be higher than the trap catch rate from the Rotoiti Mainland Island in many sampled areas. This suggests that while there are still some technical issues to resolve (detailed in Chapter 6), hair traps have the potential to become a useful non-lethal sampling tool to monitor stoat populations.

7.2 Comments on experimental design

When testing an animal's response to different stimuli there are two main test types available to a researcher. Presenting bait (or tunnel) types in succession is termed an 'acceptance trial', presenting them simultaneously is termed a 'preference trial'. Acceptance trials are more representative of the field situation, whereas preference trials are more sensitive to differences in response and tend to give less variable results (Johnstone, 1981). As the tunnels trialed in these experiments were intended for field use, it seemed more appropriate to proceed with an acceptance trial. Although these trials found that changes in tunnel design did result in different behavioural responses, all tunnels were investigated.

Therefore, future trials may need to consider using a 'preference trial' design to detect more subtle differences, predominantly for the proportion of stoats that are especially wary of tunnels, particularly as this study has demonstrated large variations in individual behaviour.

The existence of a preference for one trapping tunnel type does not necessarily preclude the animal from entering into another (Spurr and Hough, 1994). However, if an aversion to a particular tunnel type does exist then it would be necessary to exclude this from any further trapping operations. The importance of tunnel preference in the overall success of a trapping operation has not been determined. If the animals' preference could be easily accommodated then it would be an advantage to modify existing protocols to include it.

Repeated entries do provide some indication of a stoat's preference for tunnel type, but initial entry behaviour is more important for kill trap design. Therefore, although comparison of repeat entries between tunnel types does provide some useful insights into stoat behaviour, the initial encounter and entries are more important from a management perspective. Most stoats will conduct their most thorough investigation of the tunnels within the first half an hour of contact with the tunnel. The pen trials demonstrated that stoats will return to tunnels throughout the night, but in the wild foraging activity may take them away from the area.

The major limitation of the results obtained in these trials was due to the use of a relatively small sample group, which became less naïve during the course of the experiments. Firstly, the small sample size meant that not all possible responses to the tunnel could be observed, and it was difficult to gain any statistically significant results because of the large amount of behavioural variation within the group. In addition, as the stoats repeatedly interacted with the tunnels their reactions may have changed. For example the increased number of initial body entries into the smaller, open-ended tunnels may have been due to the experience gained from the first trial, not the change in end type,

although statistical analysis showed no difference between the two tunnel types for this behaviour.

Stoats become habituated to tunnels through repeated exposure, which may affect entry type on subsequent nights. The stoats used in Experiments 1 and 2 did become habituated to the tunnel over the course of each trial, however a comparison between experiments 1 and 2 showed that entry rates were higher on each of the three nights during experiment 2. Thus, previous experience with tunnels does not appear to have any long-term effects on stoats' willingness to investigate a tunnel and they may more readily investigate them on subsequent encounters. Therefore the lack of interest displayed towards the tunnels during the length trial is unlikely to be due to habituation effects.

Stoats are difficult animals to study, as an adequate sample size is often difficult to obtain in both pen and field trials. In addition, the large amount of individual variation shown by stoats mean that it is unlikely that one trapping tunnel design will be equally effective with all animals. While most stoats are willing enter almost any kind of tunnel placed in the field, there are a small proportion that will be more cautious and less likely to enter. It is this portion that is of most interest to managers charged with controlling them. Within this group there may be a further division between those animals that are wary, but may still enter tunnels under certain conditions, and those trap shy individuals that will not enter any trap, possibly because of previous experiences. Ideally, this type of study would focus on wary individuals, but they are difficult to obtain. Unfortunately, studying a captive population gives limited insight into the behaviour of trap shy stoats, because all the animals were trapped in the first place. Therefore, it is possible the behaviours observed within a captive population are simply a subset of the range of possible behavioural responses to tunnels.

There is no evidence to suggest that stoats vary their behaviour markedly in captivity (Erlinge, 1977; Robtaille and Baron, 1987; Erlinge and Sandell, 1988). However some abnormal behaviours, which have been attributed to the stress of captivity, have been

observed in the related species *Martes americana*, (Dagg, 1984) and *Mustela* sp., (Sleeman, 1989). During this trial, no previously unreported behaviours were observed, and the range of behaviours recorded were similar for all stoats. In addition all stoats were acclimatized prior to any testing. However, because of repeated human contact and adjustment to artificial surroundings it is possible that the captive stoats were less wary of new objects introduced into their surroundings.

Unpublished data from G. Hickling and C. O'Connor comparing possum behaviour at bait stations in captive and wild populations has shown negligible differences in behaviour of these two groups to the stations. To establish if captivity does affect the responses of stoats to trapping tunnels, field observations are required. While the field trials conducted in this thesis provide evidence that stoats will enter the proposed tunnel design in the field, their effectiveness may have been compromised by the presence of the hair trap. Therefore, long-term trapping sites need to be set up and monitored with time-lapse video recorders to allow for a direct comparison of captive and wild stoats' reaction to trapping tunnels.

7.3 Exploration and Play

During this study, stoats thoroughly explored and repeatedly interacted with the tunnels presented to them. "Many animals have a general tendency to explore their surroundings, i.e. approach and enter every accessible place available to them" (Barnett, 1958). It has also been suggested that animals explore novel objects and areas not so much out of a sense of curiosity or boredom with their familiar areas, but because they are frightened of new objects (Halliday, 1966). Although satiation of immediate needs, such as food or finding a mate, will motivate exploration, it is also commonly observed after these needs have been met (Barnett, 1988). The opportunity to gain knowledge of the surrounding environment may provide evolutionary benefits, as individuals with good knowledge of their environment are more likely to be able to escape predators, and find food or mates

(Cowan, 1983). Exploration of an object reduces wariness and although caution is necessary, as some unfamiliar situations may be hazardous, the new information gained may also be beneficial. Stoats were observed to spend a reasonable period of time (up to half an hour) watching the tunnel from various positions around the pen. They would often advance toward the tunnel before retreating back into cover, and this type of investigation would continue until they finally contacted the tunnel and entered it. These responses illustrate that while they may be wary of new objects placed within a familiar environment, stoats are generally neophilic toward novel stimuli. These observations also support the theory that exploration is partly motivated by the need to reduce fear in familiar surroundings (Halliday, 1966).

Tunnel placement may have affected exploratory behaviour, because of the lack of cover in the area surrounding the tunnel. It is well known that stoats prefer to move through cover whenever possible (King, 1989a). When observed in the pens they generally remained around the edges in the cover of rank grass. During the pen trials the grass was mown regularly, so it did not interfere with the view of the tunnel. Thus, it is likely that stoats would have spent a large period of time observing the tunnel before approaching it, not only because it was a novel object, but also because the area surrounding it was fairly exposed.

The initial motivation for entering the tunnels may have been to look for food, to improve knowledge of the immediate environment or determine the presence of any threat (Cowan, 1983; Barnett, 1988). For example, the closed-ended 50 mm tunnel is more typical of the natural setting in which stoats would be searching for food (Simms, 1979; Elliott *et al.*, 1996). Once the desired information had been gained there seemed no obvious reason for the stoats to investigate it further. The repeated entries could be attributed to play behaviour in many instances. While the observation pen would not be considered a sensory deprived environment, it is considerably smaller than the average

stoat home range. Stoats had been relieved of the burden of obtaining food so would have had excess energy and are naturally inquisitive animals (King, 1989a).

Play is often seen in young animals so is assigned a developmental role i.e. such as the development of hunting skills, which will be required during their adult life (Biben, 1998). Play in adults is less easily explained as these skills are already honed and used frequently to ensure survival (Hall, 1998). Object play may be considered an extension of exploratory behaviour in some circumstances as the animal gains additional information on the object while interacting with it. The addition of objects to enrich the environment of captive adult animals is common, and individuals may spend a significant proportion of their time interacting with these objects (Burghardt, 1998).

Actions that I would consider play behaviour were observed with all tunnel types, but most frequently with the 50 mm tunnels. Stoats were often observed to roll about while entering the tunnel and would enter and exit several times in quick succession, especially in the open-ended tunnels. Tunnels were also jumped over and on repeatedly, and pushed about.

Other possible explanations for the repeated investigations could be due to patrolling behaviour or the scent marks of conspecifics. Stoats are known to frequently patrol their range in the wild (Vaisfield, 1972), therefore it is possible that some of the repeat entries or approach and sniffing behaviour observed in the later part of each night could be attributed to the stoat patrolling its limited range. If the stoat had identified the tunnel as a possible source of food then it may have been checking to determine if 'prey' had returned.

Investigation of the tunnel and surrounding area through sniffing was a commonly observed behaviour during all of the experiments, whether I had attempted to mask human scent or not. There are several possible reasons for this observed behaviour, one of which is that as the tunnels were positioned in the same place during all the trials, the stoats were investigating the scent left by previous stoats. In scent marking trials, stoats were observed

to mark new objects within their pens and mark over areas where previous occupants had marked (Erlinge *et al.*, 1982). The scent marking behaviour described in Erlinge (1982) was observed on several occasions during these trials. Conversely, it could be due to the human odour left either on the tunnels or in the area, or it may have simply been a process to familiarize themselves with the new object.

It may be necessary to quantify the spatial use of pens by stoats if further captive studies are undertaken in this line of research, to determine which of the possible causes outlined above contributed to the behaviours observed. During the present study, not all appearances on the video screen were directly attributed to the tunnel, but it is not known if this is a justified assumption. The same area would need to be observed with and without objects present and the encounter rate measured.

Curiosity appears to be the biggest deciding factor as to whether or not a stoat will investigate a tunnel. Stoats' reactions did differ between tunnel types, and it is likely that this was due in part to the amount of curiosity each inspired. There are several observations from the pen trials that support this. During the length trial it appeared that the curiosity displayed by stoats in earlier trials towards the tunnels was refocused toward the battery of the motion sensor unit and the hole it was camouflaged in. This suggests that disturbance around a tunnel may detract the stoats' focus from the tunnel itself. This hypothesis could be tested by comparing responses of stoats to tunnels with and without other competing distractions, such as disturbed ground or additional objects, present.

It was thought that both visibility within a tunnel, and the ability to move through a tunnel might be important factors in a stoat's willingness to enter and re-enter a tunnel. However, the introduction of a mesh end-type in the length trial, which provided increased visibility but still restricted access, demonstrated that visibility within the tunnel may not be the most important entry factor. The low repeat entry rate of the 100 mm closed-ended tunnel may have been because it was large enough not to hold any investigative appeal yet to small to be useful as a refuge. The higher repeat entry rate of the closed-ended 50 mm

tunnel, which was also unsuitable as a refuge, may have been because stoats could not satisfactorily investigate the tunnel without entering it.

7.4 Management implications of this study

Trap spacing and placement has a large impact on the success of a trapping operation. The first task of any trapping operation is to place the traps to ensure that the maximum proportion of stoats in the area encounters them. Previous studies have shown that spacing traps too widely, or placing them next to roads may bias captures towards males (King, 1980; Murphy and Dowding, 1994). The distance from which stoats can perceive trapping tunnels is not known, neither are the cues used to detect them. If tunnels are detected visually then the current trapping tunnels designs may have an advantage over the proposed tunnels because they are significantly larger, therefore easier to detect from a distance. Although stoats do have acute vision, the importance of odour in maintaining their social structure (Erlinge *et al.*, 1982) suggests that olfactory cues may be important in tunnel detection. Long life lures based on prey or conspecific scents have proved less successful at attracting stoats than meat or egg baits (Clapperton, 1994) (Montague, 2000). However, the distance over which a stoat can detect different baits/lures has not been investigated. Therefore it is not known if the lures are unsuccessful because stoats do not perceive them from the same distance as other baits, or because they are not attractive. In addition, the scents that have been extracted may not be biologically 'meaningful'. Alternatively, the scent may resemble that of a dominant individual, and scent marking trials have shown that subordinates become uneasy in areas that have been marked by a dominant individual (Erlinge *et al.*, 1982).

Trapping studies of stoats and other mustelids commonly result in male biased captures (Buskirk and Lindstedt, 1989). The most popular explanation for this observation arises from the interaction between home range sizes (larger in males) and trap spacing. Alternate hypothesis include the suggestion that males (being larger) would perceive traps

from a greater distance than females, or males may be more curious or likely to investigate traps once they had come into contact with them (Buskirk and Lindstedt, 1989). It has also been proposed that females are more trap shy than males (King and Edgar, 1977). Several mark recapture studies have found that male mustelids are more susceptible to recapture than females (King, 1975a; Simms, 1979; King and McMillan, 1982). However, this study found no differences between the behavioural responses of male and female stoats to the tunnel types trialed. One possible explanation for this is that entering and re-entering the tunnels in this trial would have been a less traumatic experience than being caught in a live capture trap, where they were unable to escape and would have had to endure handling.

Stoats are naturally curious animals and once they have encountered a novel object such as a trap they are likely to investigate it further. I believe tunnel design is likely to play an important role in determining the probability of a stoat entering the tunnel and being caught in a trap. Although stoats may investigate the tunnel, the design has to make them interact with the trap in a manner that will result in capture or mortality. For example, during the length trial all the stoats interacted with at least one tunnel, but three of the animals would not have been killed because they did not enter the tunnels.

A recent paper on stoat colonisation rates suggests that 70% of stoats enter tunnels, but does not provide any evidence for this assumption (Choquenot *et al.*, 2001). In effect this suggests that 30% of a population would not enter a tracking tunnel. In this study only 12% of stoats (2 individuals) did not enter any of the tunnels in captivity. However, as already discussed, the behavioural responses observed represent a subset of possible reactions to the tunnels, so the actual proportion of stoats that would investigate but not enter the tunnels may be higher.

Pen trials have demonstrated significant differences in male and female food preferences (Murphy *et al.*, 1992). There has been a lot of emphasis on bait type as it is considered to influence the likelihood of capture. The use of bait in tunnels is standard

practice as it has been found to significantly increase tracking and capture rates of stoats (King, 1975b; King and Edgar, 1977; Murphy *et al.*, 2000). This research has demonstrated that bait is not necessary to entice a stoat into entering a tunnel and that stoats will repeatedly enter a trap even when they have already discovered that there is no food reward in doing so. When bait was added to tunnels during the hair trap trials it was not successful in enticing half of the study group to make more than a head entry into the tunnels. However, the olfactory lure provided by baits may be detectable from a greater distance than a trap alone, thus potentially attracting more stoats. In recent years, any new tunnel designs for stoat control in New Zealand have been developed with a 'suck it and see' approach. Tunnel dimensions are restricted by the height and width requirements of the Fenn trap; therefore the effect of tunnel design on stoat entry behaviour has been a secondary consideration. The small amount of research carried out has focused on the effects of construction materials, end type and trap camouflage on capture success, and been carried out in the field in conjunction with on going control work (Spurr and Hough, 1994; Dilks *et al.*, 1996; Miller and Elliot, 1997; Speed, 1997; Short and Renyolds, 2000). In most cases no differences were detected, but this is in part due to small sample sizes. Where tunnel design has been found to affect capture rate, there has been little follow up assessment to pinpoint which aspects are the cause.

This is the first study to examine stoat reactions to tunnel design before field use. All previous control tunnels have been designed, put to use in the field and then the capture rates used as their measure of success. However, the proportion of animals unwilling to enter that particular tunnel type is still not known. For designs that are not successful, this is a hugely inefficient process. In addition, large variations in trappability with season, and population fluctuations between years and areas (King, 1989a; Murphy and Dowding, 1995), make it difficult to gauge the success of a trapping tunnel in a short-term trial.

Determining the responses of stoats to the range of tunnel sizes currently employed in monitoring and control was an important part of this thesis. However, the primary aim

was to develop a trapping tunnel that would be suitable for use with a recently designed kill trap. Therefore, the conclusions I have drawn on the preferred tunnel design are specific to this trap type. None of the tunnels trialed in these experiments would be suitable for use with a Fenn trap as it is too large to fit into the two smaller tunnels and requires a flat surface to operate correctly, so the 150 mm tunnel is also unsuitable. However, this research does indicate that an appropriately shaped 150 mm tunnel would be suitable for use with a Fenn trap.

In many cases the results of this study are very positive for the stoat control efforts being carried out at the moment. This study has confirmed that the tunnel diameters and lengths currently used for both trapping and tracking tunnels are suitable and are unlikely to be deterring too many trappable animals. This research will be most useful for new trap designs or poison delivery systems. Alternative traps may require different tunnel parameters to operate correctly. This research provides a starting point for new tunnel design. If this trap and tunnel combination proves successful in the long term then this may also encourage more research into the behaviour of target species so the likelihood of capture is increased.

The commercially available 'Philproof' tunnel comprises a small entrance to exclude non-targets leading on to a larger chamber, which houses the bait or trap. This kind of design would be recommended from the results of this trial, as the small entrance and run through design would encourage the stoat to investigate the tunnel, while the large inner chamber may encourage the animal to settle and feed once it had entered. It would be beneficial to test whether stoats do react this way to this tunnel design.

7.5 Future tunnel design

As research continues into poisoning as an alternative to trapping, tunnel design will need to develop to accommodate the requirements of new bait delivery systems and ensure only target species are allowed access to the toxins. The 50 mm tunnels would not

be suitable for use as a poisoned egg bait station, because although eggs do fit in that size tunnel it would be difficult for stoats to feed on them. Also, observations from the pen trials suggest that stoats would not settle and feed in a tunnel that small.

Hair traps may provide a more useful long term monitoring tool than tracking tunnels as individuals could be tracked through seasons as well as providing general information on the presence of stoats in the area and the relative level of activity. More research is required into the effects of the hair collection methods on stoat entry behaviour. If a larger scale trial found that the glue based traps are not detecting a significant proportion of the population then alternative methods of hair collection, such as springs or burrs may need to be investigated.

This research shows that stoats are very willing to enter smaller tunnels than the ones currently used for Fenn traps. The use of plastic as the construction material does not seem to have deterred stoats from entering the tunnels, but the effects of different construction materials have not been conclusively determined. Although I found stoats were willing to enter plastic tunnels repeatedly, the results of a previous study indicated that plastic may be less preferred than wood (Maxwell *et al.*, 1997). Plastic is a much lighter construction material than wood and may be less prone to weathering. The major criticism of the wooden tunnels, which are commonly associated with Fenn traps, is their weight and bulkiness. These features make use in remote areas more difficult and increases the labour costs of any trapping operation as a trapper is severely limited in the number they can carry per trip.

Another aspect of tunnel design that requires further research is end type. This trial has shown that end type can significantly alter stoat entry behaviour, but I do not believe we have yet identified an optimum end type that meets the needs of the trap. In the field, mesh ends may have an advantage over solid ends, as an approaching stoat could both see and smell the bait, which may assist in encouraging them to investigate the tunnel further.

Exclusion of non-target species is a primary function of any trapping tunnel. The interaction between length and diameter plays a large role in determining a tunnel's effectiveness in excluding non-target species. As diameter decreases the number of species able to gain entry into a tunnel also decreases. Longer tunnels allow a trap to be set further back, which further reduces the risk to non-target species, particularly those animals too large to enter the tunnel but with long enough limbs or beaks to still interfere with the trap. Smaller animals may find it difficult to move too far down a small tunnel or be more reluctant to venture to far into a confined area, especially when it is dark.

The length to which the stoat will enter the tunnel, and also the length to which non-target species may enter the tunnel, determine trigger placement. The 50 mm diameter tunnels will effectively exclude most birds as it is too small for them to enter and their bills are not long enough to reach the trigger mechanism. The one exception to this may be the kiwi, although it is unlikely that a kiwi would poke its beak inside the tunnel, it is not impossible. In this case the trigger mechanism would have to be set back at least 210 mm, as male brown kiwi (*Apteryx australis*) bills can reach up to 205mm in length (Folch, 1992). Another group of particular concern may be smaller members of the Procellariidae family (petrels and shearwaters) as they will investigate most entrances while searching for breeding burrows (K.J. Wilson, Pers. Comm. 2001). In this case the tunnels and traps would be unsuitable for use on off shore islands, which species such as Fairy prions (*Pachyptila turtur*) use to breed.

While setting the trigger as far into a tunnel as possible may reduce the possibility of injury to a non-target species, it also reduced the likelihood that a stoat will contact it. Stoats were not moving as far down the 400 mm tunnels as previously thought, although meat baits placed at the end of the 400 mm tunnels during the hair trap trial were consumed if a stoat fully entered the tunnel. This suggests that triggers should not be placed further than 300 mm into the tunnel, no matter what the overall length, as even stoats that fully enter the tunnel may not contact the trigger if it is placed much further in.

At the moment trapping is the primary control tool for controlling stoat populations. King (1994) argues that stoat control is only effective in small areas for short periods, during times of high vulnerability for the species that we are trying to protect. Therefore, large-scale control is neither a feasible or beneficial goal with the control tools presently available. In many of the areas where threatened bird species are being protected, additional monitoring means that access is not an issue, so using large wooden boxes to house Fenn traps is a viable option. However, as our knowledge of individual species ecology grows, and populations within intensive managed areas such as Mainland Islands (intensively managed conservation areas) increase, it is being recognised that larger areas are required to ensure the long-term survival of these species. In order to control stoats at a larger scale, trapper efficiency needs to increase, especially as we move into more remote locations. The challenge now is to make traps that will capture a greater proportion of the population and that are more attractive to female stoats.

Recent trials on the Fenn trap has demonstrated that it is not humane under current legislation (National Animal Welfare Advisory Committee (NAWAC) draft guidelines) (B Warburton pers. comm. 2001.). In addition, recent legislative changes (Animal Welfare Act 1999 s.36) do not specify a minimum inspection period for kill traps. This change has the potential to substantially decrease the labour costs of a control operation, as traps could be checked weekly or even monthly in areas of low stoat abundance. However in areas of high stoat abundance, less frequent inspections may reduce the operations success if those traps are unable to catch for long periods of time, as once sprung, Fenn traps are useless until reset.

The new kill trap being developed will address many of these efficiency and welfare concerns, as it has the potential to kill up to 10 animals between each inspection and the mechanism should dispatch any stoat very humanely. This is the first trap to provide a viable alternative to the Fenn trap as an effective tool for controlling stoats. This research has demonstrated that tunnel design does influence stoats' behavioural responses

and this may be important to trapping success. As new control and monitoring technologies are developed, our reliance on tunnels will continue to grow, therefore it is imperative that we gain a clear understanding of the influence tunnel design may have of the success of these operations.

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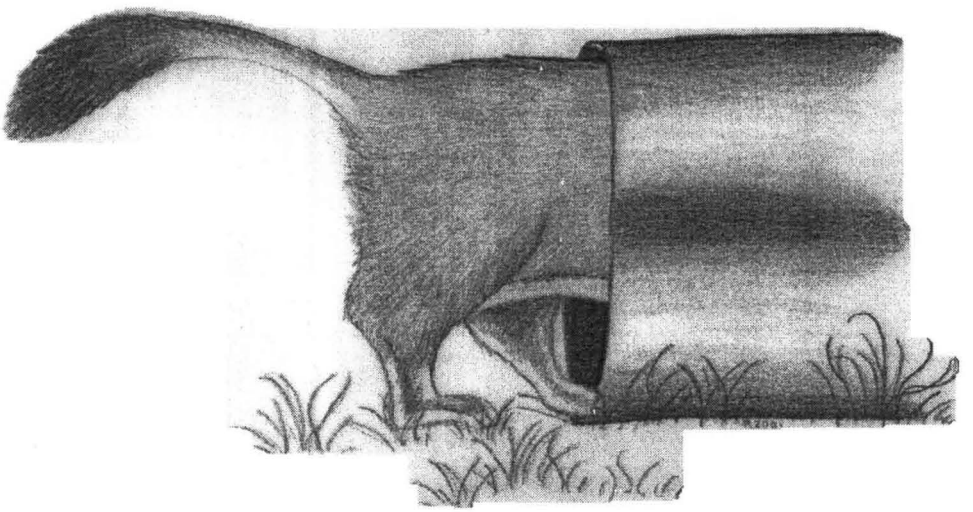

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