

Stoat Control in New Zealand:

A Review

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Table of Contents

1. Introduction	1
1.1 The need for this review	1
1.2 Control History	1
1.3 Why control? - Impacts of predation by stoats	2
2. Ecology	4
2.1 Activity	4
2.2 Habitat use in New Zealand	5
2.3 Home range	6
2.4 Diet	8
2.5 Reproduction	9
3. Control measures	10
3.1 Baits and Lures	10
3.2 Trapping	14
3.21 Trap type	14
3.22 Trap tunnels	16
3.33 Trap / Tunnel placement	17
3.34 Trap efficacy	20
3.3 Poisoning	22
3.31 1080 (Sodium monofluoroacetate)	22
3.32 Diphacinone	24
3.33 Poison-egg stations	25
3.4 Secondary poisoning	25
3.41 Secondary effects from anti-coagulants	26
3.42 Secondary effects from 1080	27
3.42 Poisoning efficacy	28
3.5 Other methods of control and damage prevention	29
3.51 Stoat and predator proof fences	29
3.52 Vegetation Buffers	29
3.53 Repellents	30
3.54 Damage prevention - predator recognition and aversion	31
3.55 Fertility and biological control	31
4. Monitoring	34
4.1 Relative density index: Trap/catch	34
4.2 Relative density index: Tracking tunnels	35
4.3 Absolute density	37
5. Conclusions and Recommendations	39
5.1 Current control methods	39
5.2 Conservation management implications	39
6. Priorities for future research	41
6.1 Current control operations	41
6.2 Priorities for the future	41
7. Acknowledgments	42
8. References; Appendix 1 - Additional references; Appendix 2 - Trap manufacturers and suppliers	

1. Introduction

The aim of this report is to review scientific knowledge relating to stoat (*Mustela erminea*) control in New Zealand, as a management tool in the conservation of native species threatened with predation by stoats in New Zealand's modern environment.

1.1 The need for this review

Monitoring of species under direct threat of predation by stoats has shown that controlling stoat populations can increase productivity and survival rates in the threatened species. Localised control of stoats by intensive trapping was found to be a viable management option to assist mohua (*Mouhousia ochrocephala*)¹ recovery (O'Donnell *et al.* 1996). Further research into the role of mammalian predation in the decline of native fauna, and development of more efficient control techniques were advocated (O'Donnell 1996; O'Donnell *et al.* 1996).

Intensive management regimes on islands supporting populations of endangered species, and the advent of the "mainland island" concept (Saunders, 1990), has opened the door for some of that research. There are now more people working on stoat control than ever before, and reduction of stoats to low or nil densities over larger areas than ever before is being attempted (pers. obsv.). However, if mainland species, such as kiwi, are to survive in current numbers, and maybe even increase, stoats will have to be controlled over areas as large as 5000 hectares (J. McLennan pers. comm). Therefore, current control measures need to be more efficient, and novel or more effective methods developed.

This review collates recent research encompassing methods of stoat control, relevant ecology and demographic responses to control. This review does not intend to be a manual of best practice, but to provide a basis for discussion amongst those working in stoat control, direction for future research and a compilation of related New Zealand literature

1.2 Control History

Members of the mustelid family were first introduced to New Zealand in the 1880's as a biological control to wild rabbits (*Oryctolagus cuniculus*)². The main instigators of these introductions were farmers who were experiencing soil erosion and economic loss as a result of rabbit grazing. In an effort to control them, their natural enemies were imported (King 1984). Prominent naturalists of the time, such as W. Buller, realised the

¹ Bird nomenclature follows Heather & Robertson 1996

² Mammal nomenclature follows King 1990

potentially disastrous effects mustelids could have on the native fauna, and strongly protested the planned introductions (Buller 1887 in King 1984). However, domestic ferrets (probably *Mustela putorius*, now known as *M. furo*) were successfully released in 1882. Stoats and weasels (*M. nivalis vulgaris*) were also released in 1884. Hundreds of these predators were turned out onto farmland worst affected by rabbits (King 1984). These areas included much of Canterbury and Otago, and parts of Southland, Marlborough and Wairarapa.

Within 10 years it became clear that the introduced carnivores were not fulfilling their primary task of rabbit control. Reports of stoats, ferrets and weasels inhabiting areas far from release sites, and feeding on native birds such as kakapo (*Strigops habroptilus*) and blue duck (*Hymenolaimus malacorynchos*) were not uncommon (Wodziki 1950; Buller 1894 in King 1984). In the 1930's legislation that had previously protected mustelids was changed and bounties were offered for mustelid tails. Between 1939 and 1948 over 37 000 stoat tails were submitted for bounty in the North Island (Wodziki 1950), Stoat skins then became valuable in the fur trade and, between 1944 and 1948, close to 51 000 skins, mostly from the South Island, were bought by one company (Wodziki 1950). These were the first attempts to control mustelid populations in New Zealand.

Marshall (1963) and Fitzgerald (1964) were among the first to describe the ecology of mustelids in New Zealand. C. M. King made a large contribution to the foundation research of stoat control and ecology with a series of papers and reports from a four-year study in the Eglinton and Hollyford Valleys, Fiordland, and subsequent studies in Craigieburn Forest Park. Stoats from fourteen National Parks were also collected and aspects of their biology, such as diet and age composition, described (King & Moody 1982).

King (1978) recognised that prevention of damage by stoats to a population meant removing individual stoats when and if they were a threat. She concluded that controlling stoats in New Zealand forest was limited by practical difficulties. Control would only be worth doing on a small scale.

1.2 Why Control? - Impacts of predation by stoats

The need to control local mustelid populations has gained importance in New Zealand as the threats to our conservation assets have become more evident (Murphy 1996b). However, the impacts of stoat predation on a bird population have been hard to measure. Stoat predation on takahe (*Porphyrio mantelli*) was studied from 1964 to 1969 (Lavers & Mills 1978) without obtaining conclusive evidence of predation effects. All

that could be reliably reported was that a decline in takahe numbers coincided with high stoat numbers (Lavers and Mills 1978).

In the 1980's studies began to determine what part predation was playing in the suspected decline of mohua the bush canary. Elliot *et al.* (1996) hypothesised that stoats pose a particular threat as they tend to inhabit forests and are adept tree climbers. This means they are able to reach the nests of birds, such as mohua, that use holes in trees as nesting sites. Evidence that the culprits were stoats and not other predators, was again indirect: mohua productivity and mortality were significantly affected by predation events in a year of high stoat densities. The predators were almost certainly stoats as no other predators were detected in the area (Elliot 1996; Elliot *et al.* 1996).

Evidence surrounding kaka (*Nestor meridionalis*) predation was examined and also found to be oblique. The parrots' survival and nesting success were seriously affected by predation on eggs, chicks and nesting females (Beggs and Wilson 1990). Only later was the main predator identified as being stoats (Wilson *et al.* 1998). Evidence supporting the hypothesis that predation by stoats is responsible for declines in many native species, including kiwi (*Apteryx* spp.), Yellow-eyed penguin (*Megadyptes antipodes*) and New Zealand dotterel (*Charadrius obscurus inquilonius*), has grown over the last few years (Innes & Hay 1991; McLennan *et al.* 1996; Miller & Elliot 1997; Moller *et al.* 1995; Dowding & Murphy 1996). Predator control operations and research has also grown with the need to protect vulnerable species from predation.

2. Ecology

The huge number of stoats killed during the bounty and fur years illustrate the difficulties associated with controlling stoats. The problem with controlling small, short-lived mammals with high annual productivity, known as "r" strategists, is that the control measure(s) must exceed the mortality rate, which in stoats is naturally high at around 70% (King & Moors 1979a; King *et al.* 1996a). Recruitment is also very high, so the control measure must be effective at reducing the target species at the population level without triggering a population response i.e. increased survival and fecundity.

Knowledge of range extent, foraging habits, activity and habitat use are aspects of the target species ecology that will increase the likelihood of effective control. King (1989; 1990) gives a detailed account of the natural history of stoats, which is advisable for those serious about understanding them to read. This section on ecology collates and reviews research published, and some aiming to be published, since then. The aim of this section is not so much to review the methodology used to achieve the results, but to give a background to the following chapter, and on the studies to date.

2.1 Activity

Stoats can be active at any time of the day or night. The rapid metabolism of mustelids means that stoats need to eat frequently, sometimes up to five or six times per day (King 1989). They tend to rest after hunting and eating, before repeating the cycle. Samson & Raymond (1995) found that stoats in Southern Quebec in summer displayed diurnal rhythm and were active for short bouts of forty minutes or less before resting. Stoats held in captivity in Quebec, foraged for bouts of 3 hours or less, with an average of 45 minutes (Raymond *et al.* 1990). Robitaille & Baron (1987) found ambient outdoor temperature and reproductive state to be the two factors having the most influence on the activity budget of captive stoats.

In New Zealand stoats have also displayed diurnal behaviour, although not exclusively. The first radio-tracking of stoats in New Zealand, in South Island beech (*Nothofagus*) forest, noted diurnal behaviour (Murphy & Dowding 1991). Their results indicated that from January to May, stoats were active for a large part of the day. However, only one stoat was followed at night so nocturnal activity was not described. In the same study, spot records (independent fixes on transmitted animals positions and activity) taken between 0730 hours and 0200 hours indicated that stoats spent significantly more time stationary in autumn than in summer. This was due to stoats moving significantly less during the day in autumn (Murphy & Dowding 1991).

In South Island coastal grasslands of Otago Peninsula, male stoats had a higher level of activity at night in autumn than in summer, and females were 77% more active at night than males (Alterio & Moller 1997). In spring, however, male stoats were more active during daylight hours in coastal grasslands (Alterio & Moller 1997) and in beech forest (Alterio 1998). However, the comparisons made of activity, between seasons, by Alterio & Moller (1997), were in the same coastal grassland habitat, but for different years and very probably different animals. Other likely confounding factors are different ambient outdoor temperatures and densities of prey abundance.

2.2 Habitat use in New Zealand

Stoats will use nearly any habitat that can provide food and den sites. Most stoats probably range across a mosaic of habitats (King *et al.* 1996a), although may tend to avoid open spaces (Murphy & Dowding 1994). Den sites may include holes up the trunks and in roots of trees through forest habitat (Murphy & Dowding 1991;1994), or logs, ditches and isolated patches of scrub in open habitat (King 1989). Water, even fast flowing rivers, are not a barrier to stoats (Murphy & Dowding 1991), and small streams may regularly be used (C. Gillies pers. comm.).

In South Island coastal grasslands, four adult male stoats used grazed and ungrazed areas equally, but were strongly attracted to habitat with cover, such as stream verges, rock walls, shelter belts and scrub patches (Alterio *et al.* 1998). However, stoats did not use tracks more often than other areas under examination in the coastal grasslands (Alterio *et al.* 1998). Also in coastal grasslands, Ratz (1997b) reported that traps placed in rank grass caught stoats 1.4 times more often than traps in other habitats.

King *et al.* (1996b) found that stoats were most abundant in older exotic forest, when compared with younger exotic plantation, logged or unlogged native forest. This comparison of habitats, within a geographic location, is the first in New Zealand to include exotic forest and showed some unexpected results. Even when mice reached a peak density in younger exotic forest, few stoats were caught there. The indices of population were taken over 7-10 days, four times per year: February, May, August and November. It may have been possible that the sampling design missed a temporary stoat irruption after the mouse irruption. Alternatively, the data suggest there may have been a better food source in the older exotic plantation than in the young. King *et al.* (1996a) report a high percentage frequency of birds in the diet of stoats from the older exotic forest.

Stoats in podocarp-hardwood forest of central North Island were patchily distributed, although it was not clear if food availability or some other resource was attracting them

to certain areas (Murphy *et al.* in press). In the same study, a significant inverse relationship between stoat and rat tracking rates was reported. The reasons for this are also, not clear, but may have been due to an interaction between the animals, or habitat preference (Murphy *et al.* in press). Previous studies within similar habitat have reported positive correlations between rat and stoat indices (King *et al.* 1996b; Murphy *et al.* 1998a).

Stoats in a North Island beech forest were caught in accordance with random expectation, except in manuka (*Leptospermum scoparium*) vegetational associations, where stoats were caught less often than randomly expected (J. McLennan pers. comm.). These results are in direct opposition to common belief and much anecdotal evidence that suggests stoats are found in "hot spots" in forest habitat. The factors influencing "hot spots" and, alternatively, random distribution require further investigation, and could have implications for trap, tunnel and bait station layout.

2.3 Home range

Home range of stoats appears to vary with habitat, sex, season and prey abundance, from 2 ha to over 2000 ha (Erlinge 1974; Sandell 1986; King 1989; Murphy & Dowding 1994; 1995; Robitaille & Raymond 1995; Miller *et al.* in prep.). Of these determining factors, prey abundance is likely to be the governing influence, for most of the time (Erlinge 1974). Stoats have larger home ranges in New Zealand than in the northern hemisphere (King 1989; Murphy & Dowding 1994; 1995; Miller *et al.* in prep.; cf. Erlinge 1977; Robitaille & Raymond 1995), which may suggest that habitat in New Zealand does not provide optimal food supply for stoats (Murphy & Dowding 1994). The exception to this may be in beech seeding (mast) years, when high densities of prey items exist and subsequently high densities of stoats (see King 1983; Murphy & Dowding 1995; Lawrence 1998). High densities of stoats and prey may lead to smaller home ranges of stoats through non-territoriality (Murphy & Dowding 1995; Alterio 1998).

A proportion of male stoats, usually the dominant ones, leave their territories during the breeding season, as searching for receptive female stoats becomes more important than prey resource (Erlinge & Sandell 1986). This searching is better described as ranging, roaming or transient behaviour, rather than maintaining a true home range. Home range studies that have been conducted during spring, i.e. the breeding season, often report large home range areas for male stoats but may just reflect the large areas a male stoat can travel during the spring.. However, male stoats in New Zealand have been found to have large home ranges in summer, one in excess of 600 ha (Murphy 1996a). Although home ranges overlap, particularly between sexes (Erlinge & Sandell

1986; Murphy & Dowding 1994; 1995; Alterio 1998), it appears that many individual stoats have separate core ranges that do not overlap (Murphy and Dowding 1995; Young 1999). Male stoats do display dominance relationships (Erlinge 1974; Robitaille & Raymond 1995) and tend to avoid each other slightly (Miller *et al.* 1998).

Table 1: Summary of New Zealand home range studies. Sp=Spring; Su=Summer; Au=Autumn; Wi=winter; M=Male; F=Female; n= Sample size; Sth Is.= South Island. Mean home range is in hectares \pm one standard error, calculated by the minimum convex polygon method (Stickel 1954)

Source	Location & Habitat.	Season	Sex	n	Home range (Hectares)	Comments
Murphy & Dowding 1994 <i>in</i> Murphy & Dowding 1995	Sth Is. Beech forest	Su/Au Su/Au	M+ F M+ F		80 \pm 7 ----- 160 \pm 35 -----	-stoat irruption year -year following stoat irruption
Murphy & Dowding 1994	Sth Is. Beech forest	Su/Au	M F	4 5	206 \pm 73 124 \pm 21	
Murphy & Dowding 1995	Sth Is. Beech forest	Su/Au	M F	3 4	93 \pm 7 69 \pm 8	
Alterio 1998	Sth Is. Beech forest	Sp	M F	4 7	223 \pm 45 94 \pm 13	
Moller & Alterio unpublished <i>in</i> Alterio 1998	Sth Is. Ungrazed grassland	Sp Au	M M	3 3	110 \pm 28 158 \pm 31	
Miller <i>et al.</i> in prep	Sth Is. Podocarp forest	Sp Au Wi Sp Su Au	M M F F F F	8 2 2 5 3 4	256 \pm 38 145 \pm 35 123 \pm 6 81 \pm 20 75 \pm 67 44 \pm 18	
C. Gillies personal communication	Northland Kauri-podocarp-hardwood fores	Su/Au Su/Au	M F	3 1	108 \pm 19 50	The female range can only be considered preliminary as she , and others, are still being followed

Few have studied home range of females during the breeding season, as female stoats can be particularly shy of capture during this time (Murphy & Dowding 1994). In Quebec, females became less active over the breeding season (Robitaille & Raymond 1995). It is presumed, therefore, that females with young are likely to stay close to their den sites. They may either have a slightly reduced home range, or, as Miller *et al.* (in prep.) report for South Island podocarp forest, maintain the same home range as in other seasons. Females will, however, shift their young between den sites. In the Eglinton Valley, an adult female moved her young 500m to a new den (Murphy & Dowding 1995). The majority of home range data in New Zealand have been collected from stoats inhabiting South Island beech forest. The marked difference between years reported by Murphy & Dowding (1995) relates to the change in food resource discussed above. Changes in age structure of the population may also be an important factor (E. Murphy pers. comm.). Recent studies in central North Island podocarp indicate that

home range of stoats there may be much smaller than in South Island beech forest. Despite habitat and resource differences, they commonly appear to be home ranges, of either sex, of approximately 100 ha in the South Island. Current home range investigations in kauri (*Agathis australis*), and hardwood forest in the North Island will help to clarify this.

2.4 Diet

Stoats are flexible and opportunist in their diet (Murphy & Dowding 1995). Availability of prey is the main influencing factor. A change in abundance of prey may cause a diet shift, as shown by Murphy & Bradfield (1992) and Murphy *et al.* 1998 after a rat (*Rattus* spp.) poisoning operations reduced rat abundance, where rats had previously been a major dietary component. Murphy & Dowding (1994) document the change in frequency occurrence of prey categories (the proportion of guts examined containing the prey item) through the irruption and subsequent population fall of prey items and stoats after a beech seed-fall. Stoats consumed large numbers of mice (*Mus musculus*) when mice were at a population peak (1990/90), and the following year (1991/92) no rodents were detected in the diet of stoats. Similar results were obtained in 1992/93 (Murphy & Dowding 1995).

In New Zealand rats, birds, lagomorphs (rabbits and hares [*Lepus europaeus occidentalis*]) and mice are major items of prey (see Table 2) in habitats where they are available. Invertebrates, such as weta (Order: Orthoptera) make up a large percentage of frequency of occurrence but, because each item is small, a much smaller proportion of diet by weight frequency.

Separation is apparent between the sexes feeding niche (King & Moody 1982b; Raymond *et al.* 1990). Females tend to specialise in smaller prey species (eg. mice and insects), and males, who are generally larger themselves (Erlinge 1989; Powell & King 1997) tend to consume larger prey (eg. rabbits) (King & Moody 1982b; King *et al.* 1996; Alterio & Moller 1997). Male stoats may scavenge carrion more readily than females (Murphy & Dowding 1994). Prey items of medium size, such as rats and bird species, tend to be eaten in equal proportions (King & Moody 1982b). However, this behaviour pattern is not exclusive. For instance, male stoats ate more mice than females in podocarp/hardwood/exotic forest (King *et al.* 1996a), probably because of the availability of mice in that habitat.

Table 2: Summary of diet analyses in New Zealand, presented as % frequency occurrence of prey identified in stoat guts. Invert.=invertebrate; Others includes skink, gecko, bird egg, hedgehog, freshwater crayfish, fish; Un-ID=unidentified. All source material is published.

Source Habitat Season	Year of study	n	Lago morph	Poss-um	Bird	Rat	Mouse	Inve rt.	Other	Un-ID	Comments
King & Moody 1982; see comments.	1972 -76	1250	10	17.5	42.6	6.4	19.3	46.5	10.9		14 collection points; 9 habitats; all seasons
Murphy & Dowding 1991; Sth Is. beech Forest; Dec-May	1990/91	54	7	2	57		54	22			year after seedfall; females ate more mice
Murphy & Bradfield 1992; Podocarp - Hardwood; all seasons	1989/90	17	12		6	71	6	6	0	6	shift in diet after reduction in major prey item
	1990/91	18	17		56	17	0	17	6	6	
Murphy & Dowding 1994; Sth Is. beech Forest; Oct-May	1991/92	26	23	12	54			31		8	year of high stoat density but low rodent density; See text
King <i>et al.</i> 1996; Podocarp, hardwood, exotic;	Jan 83 - Oct 87 all season	52	combined 3 5		38	21	13	56	4		males ate more mice; combined lagomorph + poss. included unid. mammals
Alterio & Moller 1997; Otago grasslands; all seasons	1983-93	75	35		31	1	23	11	13		
C. Gillies pers. comm.; Northland; forest, forest-pasture and coastal; all seasons	1995-97	57	11	2	21	26	17.5	28	20		

2.5 Reproduction

The following is taken from King & Moody (1982) and King (1983a). Reproductive aspects that relate to control include the fact that virtually all females, young (5-8 weeks) and old, are impregnated during the breeding season in late spring, early summer. A long period of 9-10 months of delayed implantation follows, with implantation, proper gestation (4 weeks) and birth taking place in August to October. This means that controlling male stoats to very low levels will have no effects on the young of the year, or the next years population. Average litter size is 6. In times of low food supply the delayed blastocysts can be reabsorbed into the females body. High

food supply at copulation time can increase ovulation rate, with up to 19 eggs released; high food supply at birth can increase chances of the young surviving.

3. Control Measures

Stoats have been controlled in Britain for centuries, mainly to protect game birds from predation (Reynolds & Tapper 1996). The gamekeeper's traditional method of control has been trapping and their techniques are described by King (1973a; 1973b). King & Edgar (1977) review the traditional techniques, and develop improved methods for trapping and footprint tracking, which are still widely used today. The Fenn trap was brought into New Zealand in 1972, and is now the most commonly used kill trap for controlling stoats in New Zealand.

There has, however, been a constant drive to improve the way stoats are controlled. Researchers, managers and field workers have all been trying to invent ways of doing things more efficiently and effectively. This review includes published and unpublished internal Department of Conservation (DoC) reports, research published by DoC, and literature published in scientific journals. Published literature undergoes peer review generally requires a high standard of science. Unpublished or internal reports may, or may not, adhere to the same standards. For this reason, tables in this section note literature sourced from unpublished or internal reports. The biggest problem with studies involving stoats is small sample size, in particular small samples of female stoats. Replication through space and time is also difficult, particularly in areas where manipulations of low density populations have been ongoing for several years. This makes it difficult to obtain reliable results.

3.1 Baits and Lures

Although not a control measure in itself, efficient control requires effective attractants, no matter what type of control method is used. There are two types of attractant, baits and lures. Bait takes advantage of a species need to eat i.e. hunger, and are therefore most effective when usual food supplies are low. Lures are usually a smell, sound or sight that attracts the curiosity of a species.

The standard bait of two eggs, one left whole and one cracked to provide an olfactory lure, as described in King *et al.* (1994), was derived from the trials done by Dilks *et al.* (1996) (see Table 3). However, these trials were conducted by testing a different bait alternative against the standard egg bait in each trapping season, thereby creating a sampling bias toward the eggs. Baits were not rotated around the trap sites to exclude trap site preference from also biasing results, except for the trial of the anal-scent lure. Tunnel design was also being tested while the 'anal-scent lure'

and '1 whole egg' baits were being tested, which may also have confounded results. These trials can not be considered conclusive. More recently standard egg bait was tested against plastic eggs and a fish-based waxy bait (Maxwell *et al.* 1996). Eggs caught a higher proportion of stoats, although tunnels were not rotated around sites,

Table 3: Summary of trials to attract stoats to tunnels and traps by baits. *n*= sample size; PT lure = 2 propylthietane - a synthetic lure containing anal sac secretions; egg = 1 whole egg + 1 cracked egg. Significance was determined in all trials at the $\alpha = 0.05$ level. N/S = not significant; M=male ; F=female

SOURCE	TEST	n	RESULT	COMMENT
King 1973b	Fresh blood Pheasants eggs Aniseed Rabbit gut smeared on tunnels + dead mouse inside		Best result from the rabbit gut and mouse combination.	No sample size given Trial done in U.K.
Murphy <i>et al.</i> 1992; published internal DoC report. Captive trial - wild caught stoats from Sth Is. beech forest	Catfood (sardine) vs. Dead mice vs. Eggs (broken)	72 (3M;3F)	Females ate more mice; males ate more eggs. Both eaten more often than catfood	These trials all done with captive stoats - 3 male and 3 female. All choice tests.
	Deer udder vs. Eggs (broken)	12 (3M;3F)	Eggs appear to be more attractive than deer udder	Can be considered a preliminary trial only
	Deer udder vs. Dead mice	6 (3M;3F)	Deer udder appears no more attractive than mice	Can be considered a preliminary trial only
	Sardine catfood vs. Beef catfood vs. Chicken/turkey catfood.	6 (3M;3F)	Males seemed to prefer chicken/turkey catfood over others	Can be considered a preliminary trial only
Dilks <i>et al.</i> 1996 Sth. Is. beech forest.	Egg vs. PT lure* +1 whole egg	62 M=47 F=15	Males preferred eggs; females no significant difference.	Baits were rotated. 44 of 47 males & 12 of 15 females were juvenile
		30	Eggs were preferred by males.	Data from 1 st night of capture only. no sex + age but likely to be mainly juv. males
	Egg vs. 1 whole egg	29 M=18 F=11 All adult	Males preferred the standard egg bait; females showed no significant difference	Baits not rotated on trap sites to exclude bias from site preference.
		18	Whole egg was preferred by both male and female	Data from 1 st night of capture only; no sex + age given
	Egg vs. boiled egg	14 M=10 F=4	N/S	Baits not rotated on trap sites; females all juvenile
	Egg vs. Possum meat vs. Catfood -(tuna) vs. No bait	19 M=5 F=8	N/S	Baits not rotated on trap sites; 6 stoats unidentified. very small sample sizes.
	Egg vs. dead mouse	18 M=13 F=5	N/S although twice as many (12:6) caught by mice	Baits not rotated on trap sites.

Maxwell <i>et al.</i> 1999 (unpublished) Sth. Is. beech forest.	Egg vs. Wax -fish based vs. plastic egg	28 M=12 F=16	Eggs caught 20 of the 28 stoats; tunnels trailed also -could confound results	Baits were not rotated to exclude bias from site preference
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and tunnel design was also being tested. Results may have been confounded by this. However, eggs are used widely and thought to be most convenient as they last longer in the field before requiring replacement and are easy to handle and set in the field (King *et al.* 1994; Dilks *et al.* 1996).

The majority of bait trials have been performed in South Island beech forest (see Table 3) and should be repeated in other habitats. Nearly all of the trials have suffered from small sample size or poor sample design. Some of the data presented in Table 3 indicate that males may have a preference for eggs, while female stoats seem to prefer mice. The continued use of hen eggs may be adding to the sex bias towards males already found in most trapping samples (Buskirk & Lindstedt 1989; King 1989). It is not clear whether females find it harder to break into hens eggs than males, and if the use of punctured eggs or smaller pheasants eggs would make a difference. Although these remedies have been suggested (Spurr & Hough 1997), I have not found any trials that test the hypothesis. A device that holds the egg, so that stoats can get a purchase on it and break in, may also help.

Despite the recommendation to use egg baits, many trappers use fresh rabbit successfully (pers. obsv.) which was not tested by Dilks *et al.* (1996). It may well be that successful baits differ with location, and with the natural diet of stoats in that location. A problem encountered when using meat, such as dead mouse, rabbit or chicken, is that non-target catches, such as rats increase and wasps can destroy bait within a few hours in autumn (J. McLennan pers. comm.). A dried-meat bait or scent lure could be successful. Although pre-baiting has not been formally tested, it may be a good way to take advantage of the stoats ability to learn. Once a meal is found that requires little energy expent on catching, stoats will often return to where the food was found.

It must be asked why bird, such as chicken, has never been tested as a bait or lure for stoats, although some trappers do use day old chicks as bait. If the diet of stoats nationwide is studied (see pg 9) birds make up a large percentage by frequency of the diet over most areas and in nearly all seasons, except sometimes in autumn (King & Moody 1982; Murphy & Dowding 1995). It would seem only logical, then, to examine birds as a bait that could attract stoats in all areas, through all seasons. Chicken, or other bird carcasses, may deteriorate quickly, but in traps that, legally, have to be checked every day (see section 3.21) it may be a feasible option. In the

one preliminary trial that did contain bird in a catfood (chicken and turkey) male stoats seemed to prefer this flavour (Murphy *et al.* 1992).

Natural lures include rabbit gut rubbed over the tunnel covering the traps (King 1973; King 1980; King *et al.* 1994), or a piece of rabbit or other bait hung in a tree above the tunnel or trap (A. Elbers pers. comm.). Live mice as lures have undergone preliminary testing and found to catch no more stoats than dead lures and may have caused a slight avoidance of traps, although sample sizes were small (Flux & Bradfield unpubl. data; Dilks 1997). There may also be concerns from animal welfare groups at the use of live lures. An innovative design for live mice lures is currently being tested. A pipe is fixed to the side of trap tunnels, with a hole large enough for only mice to enter. The pipe contains a feeder delivering mouse food. The mice can leave or enter the pipe at any time. It is hoped that mice will learn to live in the pipes, their presence and scent acting as a lure to the trap (J. McLennan pers. comm.)

A synthetic lure was developed (Clapperton 1991) that copied components of anal sac secretions used for scent marking and social communication among mustelids (Erlinge *et al.* 1982; Erlinge & Sandell 1988). The synthetic lures attract ferrets, but have not performed well in field trials to attract stoats (Clapperton *et al.* 1994; Dilks. *et al.* 1996). Real anal sac secretions taken from stoats were tested recently (Clapperton *et al.* subm.) and results suggest the sent lures could be useful for indexing stoat populations, as the presence of lures significantly increased footprint tracking rates by stoats. Rat and mouse tracking rates were not significantly affected by the presence of the scent lure, which remained viable for over 4 weeks (Clapperton *et al.* subm.). However the same scent lure was also tested at trapping tunnels, and got no response at all (J. McLennan pers. comm.). Clearly, further research is required into the mechanisms that determine a response, and to identify the attractive components of the sac secretions, which may enable a synthetic imitation to be developed.

Other lures under investigation include sound and sight lures such as mice and hen chick noises (Spurr & O'Connor in prep.) and the colour yellow (H. Moller pers. comm.). Sound lures trialled in the past have been distress calls of starlings (*Sturnus vulgaris*), silvereye (*Zosterps lateralis*) and house sparrow (*Passer domesticus*) as analogue recordings. There was no significant difference in the number or duration of stoat visits to tunnels with or without bird calls (Spurr & O'Connor in prep.). More recently, digitally recorded calls of day-old hen chicks, mice and stoat barks were choice-tested as a lure to attract wild caught stoats to enter tunnels. However, most stoats (n= 4 F + 5 M) seldom entered either of the tunnels. Stoats that did enter the tunnel with the sound lure stayed for a significantly longer period during the first 5 minutes, than non-lured tunnels. Significantly more stoats entered tunnels with a sound lure in the first 5

minutes after a 10 second call was played, than non-lured tunnels (Spurr & O'Connor in prep.). Sample sizes were small, and the authors concluded that the sounds were not attractive enough to stoats to be trialled in the field.

King (1973) notes that fresh scats seemed to be an effective lure, but never tested the observation against any other bait or lure. An English book on trapping predators advises that "the contents of a bitch weasel's bladder may be used to great advantage." (The Game Conservancy, Predator and Squirrel Control, pp 38).

3.2 Trapping

Trapping is the usual method of control in New Zealand. Trapping is, however, labour intensive and costly (Ratz 1997b). Trap efficacy is therefore of the utmost importance, and involves selecting the correct trap type, bait, layout, position, seasonal timing and length of operation to suit the conservation purpose. Trapping does provide fresh carcasses from which much information, such as diet and age structure, can be gained.

3.21 Trap type

Choosing the most effective trap type for the purpose increases the efficiency of the trapping operation, decreases costs and maximises the chance of catching the last resident animals, especially on island situations (Ratz 1997b). This section gives a brief review of the trap types available for use in controlling stoats. Manufacturers of traps are given in Appendix 1.

KILL TRAPS: all kill traps must be, by law (Animals Protection Act 1960), checked every 24 hours.

- **Fenn trap:** 2 sizes, Mk 4 and Mk 6 - Mk 6 is recommended for stoat capture by the manufacturers; requires tunnel to cover traps against non target species; regarded as a humane trap; may be more effective if checked twice daily (Murphy & Dowding 1991).
- **Conibear traps:** developed in the United States, these are currently being used and tested for efficacy by 3 stoat researchers in New Zealand, with a tree set performing particularly well (J. McLennan pers. comm.).
- **Timms trap:** has only been trialled for stoats on one occasion but was quite successful, catching more stoats than victors, Elliots, and cage traps (Ratz 1997b).
- **Sentinel self -resetting kill trap:** developed in 1998 this trap is under trial at the moment.

- Wall of Death trap: currently under development by Tararua Weka Trust (Steve Collings pers. comm.).

LIVE TRAPS:

- Edgar live traps: developed by and fully described in King & Edgar (1977), some trappers find the design needs some alterations to the treadle plate and the release mechanism (A.Elbers pers.comm.), especially if the wood out of which the trap is made swells; some trappers dip the whole trap in linseed oil to prevent the wood swelling (King 1994) but this has not been tested for effect on capture rate; some researchers have had the design made in plastic.
- Continental seesaw, tip or wooden treadle trap: similar to the Edgar trap but without the release mechanism; this was the original design on which the Edgar was based; in one preliminary trial Edgars caught twice as many stoats as continentals; further trials needed to determine any difference in catch rates.
- Elliot trap: metal collapsible trapeze shape, easily transported in the field; because metal has minimal insulation, a nest box needs to be attached if stoats are needed alive (E. Murphy pers. comm.); preliminary trials indicate that male stoats may be caught more often in Elliot traps than Edgars (P.Dilks pers. comm.).
- Victor 1¹/₂ soft jaw leg hold trap: While this trap can be used for live trapping, and does not usually immediately kill stoats, if a stoat is caught in one of these they often die of exposure by the time the trap is checked. Some trappers use the leg hold trap very successfully as an "open set" i.e. no tunnel kill trap. This can only be done in areas where there is no risk of catching a vulnerable non-target species such as kiwi (D. Murray pers. comm.; A. Elbers pers. comm.; Ratz 1997b) A design defect of the trap is that the treadle plate can drop down too far and stop the jaws from closing (Mudford & Elbers 1995)
- Cage traps: Cage traps are not recommended for live capture of stoats as they either die from exposure or escape between the metal bars. However, cage traps can be modified with small-mesh chicken-wire wrapped around the trap, and some nesting material within the cage. This then enables the one trap to be used for all predator trapping.

Dipping the whole trap in a fish based oil is recommended for Fenn traps by King *et al.* (1994), to take the artificial smell off new traps, and to prevent rust. However, recent trials have shown that fish oil may act as a repellent to stoats (Rudolph 1998), rather than an attractant (see section 3.53). If oil must be used, vegetable oil is may be a better choice.

3.22 Trap Tunnels

A tunnel should provide four functions as it covers a trap. It should exclude non-target species, direct the target species onto the trap, camouflage the trap to some degree and protect the trap from the elements. The wooden tunnel advocated in King *et al.* (1994) does indeed fulfill these functions. It is however, heavy and awkward to carry and place any number in the field, especially over difficult terrain. This has prompted the design of different tunnels, and their trial, by many that work in the field. A heavy-duty plastic tunnel, in white or black, is commercially available (Phil Thompson, Philproof feeders, 82 Bankier Rd., RD 2, Taupiri, Waikato). While nearly all the trials (Table 4) have shown no significant difference in catch rates between tunnel types, some of the trials were poorly designed, without site rotation and little replication. Tunnel position has been found to have a major effect on catch rate (Dilks *et al.* 1996; Ratz 1997). Future trials should rotate the tunnel types to exclude bias from site preference, and should include a robust test of the commercially available plastic tunnels, as these are presently being widely used.

Some trappers prefer to use a tunnel with no base and camouflage the trap in a depression in the ground and cover with leaves or twigs. This has been shown to make servicing the trap more difficult, and to risk interference to the trap mechanism with leaf litter and twigs (Dilks *et al.* 1996). The data from Table 4 indicate no significant difference in catch rates between tunnels with bases and tunnels without. Maxwell *et al.* (1997; 1999) recorded the greatest proportion of stoat captures in wooden, open (2-ended) tunnels, although there was no statistically significant preference for any tunnel type. However, the results reported in Maxwell *et al.* (1999) were conducted in conjunction with a bait trial, which may have confounded results.

Ease of use is a major point of difference between tunnels. As mentioned, the wooden tunnels are difficult to set up initially, but relatively easy to service as the sliding lid enables quick access to traps inside. Maxwell *et al.* (1999) and Maxwell *et al.* (1997) had problems with Fenn trap safety catches sticking on the side of the wooden tunnel. Increasing the inside dimensions of the tunnel should obviate this. Wire mesh tunnels are easy to check, although Fenn trap safety catches can get caught in them (Rudolph 1998). Aluminium tunnels can be time consuming if they have to be pegged down (Maxwell *et al.* 1997).

Table 4: Summary of tunnel, material and design, trials. Significance was determined in all trials at the $\mu = 0.05$ level. N/S = not significant; M=male; F=female; Al = aluminium.

SOURCE	TEST	N	RESULT	COMMENTS
Dilks <i>et al.</i> 1996	Base vs. no base; replicated over 2 years	M=28 F=15	N/S	Tunnels were set alternatively but not rotated so site preference may have had some influence.
	Single entrance vs. double entrance	M=9; F=5	N/S	
K.Olsen 1994; unpubl. DoC report	Wooden vs. Aluminium	9	7 caught in wooden, 2 in aluminium	Al. at 68 sites, wooden as well at every second site; choice-test indicated wooden were better but sample size low.
Spurr & Hough 1994; internal DoC publication	Wooden vs. Aluminium	1F- c 3 f	N/S difference in behaviour to tunnels	c=captive f=field: unknown age + sex videoed reactions to tunnel type.
Maxwell <i>et al.</i> 1997 DoC publication	wood,open,floor vs. wood, blind,floor vs. al.no floor, open vs. al.no floor, blind vs. Square mesh ** vs. Chicken wire	7 12 11 11 7 8	N/S difference between any tunnels. No age or sex of stoats given	Tunnels rotated on sites Al.=aluminium Chicken wire was easily squashed by weka
Maxwell <i>et al.</i> 1999; unpubl. DoC report	Wooden -open vs. Wooden - blind vs. Aluminium - open vs. Aluminium - blind vs. Sq. mesh,no floor, blind vs. Sq. mesh, floor,blind	2F,1M 4F,7M 3F 5F,2M 3F,1M	N/S difference between any tunnels.	Tunnels were set in repeating sequence but not moved so site preference is like to have had more influence than tunnel preference; also run in conjunction with a bait trial which may also have confounded results.

** Square mesh design by I. McFadden described in Sim & Saunders (1997).

3.23 Trap / Tunnel placement

TRAP POSITION: The position of a trap and tunnel can have a big influence on catch rates (Dilks *et al.* 1996). Some traps will continually catch more stoats than others will. For example, Maxwell *et al.* (1999) caught 28 stoats on 16 traps out of a total of 120 traps. Two of the traps caught 3 stoats, 8 traps caught 2 stoats each, 6 traps caught 1 stoat each and 104 traps caught none. This means that some sites are naturally preferred over others. There have been some efforts to document the characteristics of sites in which stoats are more often or continually caught (Dilks *et al.* 1996; DoC 1998a; J. McLennan pers. comm.). However, further analysis of the phenomena may help increase trapping efficiency. King (1973a; 1980, 1994) recommends that unsuccessful traps should be shifted. Sometimes a shift of just a few metres will increase the catch rate of that trap (A. Elbers pers. comm). However, traps that have never caught anything before may, for no apparent reason, suddenly start to catch (Crouchley 1994).

A good place to position a trap and tunnel is on a local regular hunting runway (Gossow 1970), such as under a hedge. King (1973a; 1980; 1989) suggests the placing of traps on runways in most of her publications. The problem with this advice is that it takes experience to recognise stoat runways and habitats, especially in forest habitat. There are no noticeable pads, such as with possum runs. Stoat runways are often at junctions of microhabitats such as the edge of rank grass and pasture, or fallen logs and tree root systems in forest (Gossow 1970; A. Elbers pers. comm.). Traps placed near obvious food sources may have greater success (Murphy & Dowding 1991). Riparian zones seem to be a major zone of use for stoats (Doyle 1990) and should be concentrated on when placing traps in the field. One successful trapper takes advantage of the stoats habit of retreating into cover by placing an open set victor in a small hand-made tunnel in thick vegetation, then placing a bait just outside the vegetation (A. Elbers pers. comm.). Stoats are often caught by the back leg as they drag the bait under cover.

Rudolph (1998) reported the highest capture frequency of stoats beside rivers, the next highest being on ridges. There was, however, unequal opportunity for a stoat to be caught at each location. There was 3.8 to 6 times more effort put into trapping on ridges than at streams, rivers, river terraces or faces. This was probably due to ease of access to the ridges. For trapping efficacy, though, it is more effective to put greater time and effort into servicing traps around streams or rivers.

Mudford & Elbers (1995) recommend that the trapper or planner spend at least a day assessing the area for potential trap sites. Places to look at are possible access points for stoats such as gullies and ridges, potential hunting and foraging areas, linkage points such as a line of trees, or paths made by other species like possums, stock or people (Mudford & Elbers 1995). If trapping to protect an island from invasion, then access points may be the closest point from the mainland, or areas that currents run to (Crouchley 1994).

TRAP SPACING: Spacing and layout of traps will determine the proportion of the overall stoat population caught and the proportion of females caught (King 1994). Closely spaced traps should, in theory, catch an equal or higher proportion of females. However, in springtime females are particularly wary, and even traps placed outside a females den may not catch her (Murphy & Dowding 1991). The aim of the control operation will decide the proportion of the population to be targeted. For example, if trying to prevent predation on a particular species for a short time while that species is particularly vulnerable, then intensive spacing (100m) is advised, to catch as many individuals in that area as possible (see Dilks *et al.* 1992;

King 1994; O'Donnell *et al.* 1996; McKinlay *et al.* 1997). On the other hand, if trying to reduce the population of stoats over a large area over a longer period, it is probably more cost-effective to space traps further apart. It is presumed this will catch a smaller proportion of a much larger population (King 1994).

Trials in the Eglinton Valley are currently under way to assess the effectiveness of sustained control by more widely spaced (200m) traps run along a single line (DoC 1998a). This area has been the study site for much stoat research, and also contains a population of mohua (King 1978; Dilks *et al.* 1996; Elliot 1996; O'Donnell *et al.* 1996). Consequently the stoat population in the area has been manipulated for over 20 years. Trials for sustained trapping should be repeated in an area not so intensively controlled in previous years.

King (1980) tested 100m, 200m, 400m, and 800m spacing in a line along the road in Eglinton valley, with a replication in Hollyford valley. No significant difference was found between the numbers of stoats caught at each spacing. There was no way of determining what proportion of the population were being caught at the different spacings. A volunteer also ran a line of traps at 2100m spacing at the same time. Male stoats made up 76% of all stoats caught at that linear spacing, although adult male stoats utilise road habitat significantly more than females (Murphy & Dowding 1991). However, King & McMillan (1982) caught similar numbers of males (n=77) and females (n=55) in live-traps spaced at 400m, although over 80% were juveniles.

Lawrence & O'Donnell (in prep.) have tested different layouts of traps to protect breeding mohua. The usual layout for intensive control is a grid of 100m x 100m spacing covering the area to be protected from predation. This is extremely costly, but is effective (O'Donnell *et al.* 1996). Lawrence & O'Donnell (unpublished data *in* Lawrence & O'Donnell in prep.) tested straight lines of traps to protect mohua populations, but found that only the area within 1200m of the lines was protected. From 1992 -1995 Lawrence & O'Donnell (in prep.) trialled 3 layouts over 45 and 90 hectares. Two study sites were used, at which it was assumed there were similar stoat abundance, and the layouts were rotated between them. The layouts were i) a perimeter only, ii) a perimeter with a median line, and iii) a conventional 100m x 100m grid layout. There was no significant difference in the average time it took to kill the available stoats in the perimeter layout compared with the grid layout. Perimeter layouts around 45 hectares and 90 hectares are as effective at removing stoats as grids, in terms of time. However sample sizes were small (n= 7-12 kills per layout per year), and a perimeter layout does not guarantee the protection that a grid layout does. For example, if a female stoat and her young stay within a few hundred metres of her den,

within the perimeter, they may never encounter the traps. In a year of high stoat densities, home ranges may be so small (Murphy & Dowding 1995) that a perimeter trap may not be encountered (Lawrence & O'Donnell in prep.)

Further trials of layouts could indicate a better use of the available trapping resource. Perhaps a trial of perimeter traps spaced at 75m and two or three internal lines may prove an effective layout.

3.24 Trap efficacy

In the current environment of limited resources, getting the maximum benefit for minimum amount of trapping effort is important. Monitoring is needed of both the conservation asset being protected, and the target predatory species. This monitoring should be aimed at population levels, not the number of animals killed or present. Monitoring techniques are discussed in Chapter 4. The information gained from monitoring should help to decide how long to trap for at any given time, and when to resume trapping..

How long does it take to remove stoats from an area? Lawrence & O'Donnell (in prep.) found it took an average of 7.65 weeks to kill all the available stoats on either perimeter or grid layouts over an area of up to 90 ha in mountain beech (*Nothofagus solandri* var. *cliffortoides*) forest. Ratz (1997b) calculated that 58% of the estimated resident stoats were removed in 8 days (80% Confidence intervals (C.I.) 32.3 - 78.0%) in Otago coastal grasslands.

The practical problem with both these estimates is that they are calculated using Zippon Removal Graphs (Zippon 1958) which assume that all animals are equally trappable. All stoats are not equally trappable. King (1989) suggests that only 50% of the stoat population is trappable.

King & McMillan (1982) recaptured only 11 (52%) of 21 marked stoats in a week's trapping. Fechny *et al.* (1993) found that a Department of Conservation predator control program for Yellow-eyed penguins failed to remove 5 pre-tagged stoats. Of 22 transmitted stoats in the Dart Valley, only 12 were recaptured (B. Lawrence pers. comm.). In a live trapping program designed to test the efficiency of a kill trapping line, 4 stoats were caught alive. One died at initial capture and only one of the remaining 3 was subsequently caught in a kill trap (DoC 1998a). In a recent captive trial for sound lures, it was noted that stoats only entered tunnels on 10-15% of visits to tunnels (Spurr & O'Conner in prep.). Video-footage of poison trials, in the field, revealed that on 20% of approaches to tunnels, stoats did not enter (P. Dilks pers.

comm.). The proportion of the stoat population that will not enter a tunnel, or are otherwise untrappable, is an area that urgently needs research.

Alterio *et al.* (subm.) report that stoats were retrapped more often when densities of stoats were low in a South Island beech forest, and suggest the scarcity of mice, and subsequent hunger of stoats, as being the causal factor. However, rats had increased tunnel tracking rates at the time and were likely to be available prey. An alternative explanation of the more "trappable" animals may be that stoat densities may have been higher than reported (see section 4.3), and home ranges possibly smaller than estimated, and therefore stoats may have been more likely to encounter traps.

Once stoats have been removed from an area, how long before re-invasion occurs? It is assumed that killed individuals will be replaced shortly after their removal (Ratz 1997b) but surely this depends upon the habitat and time of year. For example, Deer Flat was re-invaded within 2 months after trapping ended (Murphy & Dowding 1994). This was, however, in autumn, in a year of high densities of adult stoats (Murphy & Dowding 1995) and mice were scarce in the diet of stoats (Murphy & Dowding 1994). Home ranges were twice the size of the previous year (Murphy & Dowding 1995). It is likely that adults were hungry and searching for food over a much larger area than normal.

Stoat footprints disappeared from tracking tunnels for a period of nine consecutive weeks after a poisoning operation on Otago Peninsular (Alterio 1996). Five stoats (1 F, 4 M) were caught in the area by Fenn trap 12 - 14 weeks after the poisoning (Alterio 1996). This was, however during the winter months when activity of stoats is normally low (Robitaille & Baron 1987). There were also ferrets re-invading the territory, which may have resulted in stoats avoiding the area (Pierce 1987; Ratz 1997b).

In podocarp-hardwood forest of central North Island, mustelid tracks were not detected in lines of tracking tunnels for 12 weeks after secondary poisoning killed the resident stoats (Murphy *et al.* in press). The area that had contained the most dense stoat population prior to the poisoning was also the first to be re-invaded.

All reports of re-invasion times and rates rely on detection of all individuals present, which may, or may not, be achieved. A re-invasion model that can incorporate habitat, prey abundance, population densities of stoats and time of year would be very helpful in planning control operations.

Until such a model is designed, King (1994) suggests that pulsed trappings of 7 - 14 days will catch the greatest number of stoats for the least amount of effort as capture rate tends to decrease after the first few days. In a mark and recapture programme,

Alterio *et al.* (subm) live-trapped over two separate periods of 14 days in January and February, and 11 days in August and September, and encountered few new stoats over the last 6 days of either trapping period. Cross *et al.* (1998) found that the cost-efficiency of removing 80% of a population of ferrets was 3 times that of removing 50% of the population. Pulse trapping is probably the most cost-effective routine of trapping, known to date, to continuously remove re-invading populations.

3.3 Poisoning

Poisoning can be a more cost-effective method than trapping to control a target species (Ratz 1997; K. Brown pers. comm.). Poison bait does not legally have to be checked every day so is not as labour intensive as trapping. Two poisons have been trialled for effectiveness at directly poisoning stoats. These are 1080 (Sodium monofluoroacetate) and diphacinone, a second-generation anticoagulant. All trials to date have used hens' eggs as a bait in which to carry the poison. The advantage of using eggs is that they may last up to one month in cool climates (Spurr & Hough 1997), and are easy to carry and place in the field. The disadvantages of eggs are discussed in section 3.1. Full instructions for using poisoned hens' eggs are given in Spurr & Hough (1997).

Other poisons are currently being considered and trialled as alternatives, including cholecalciferol (E. Spurr pers. comm.). Encapsulated cyanide has recently been put on the commercial market for possum control and deserves examination as a poison for stoats. However, this would be reliant on a suitable bait to distribute cyanide in being developed.

3.31 1080 (Sodium monofluoroacetate)

Mustelids are susceptible to poisoning by 1080. The first evidence for this statement came from Marshall's (1963) experiment on ferrets. He found that 1.0 mg. kg.⁻¹ live weight was insufficient to kill ferrets. At a higher rate of 1.25 mg. kg.⁻¹ ferrets died within approximately 8 hours. 1080 is an acute poison and usually kills animals within 12 hours of a lethal dose (DoC 1997). Stoat controllers have only recently realised the potential advantages of 1080 poisoning over trapping, and indeed over other poisons, and begun trial work.

Captive trials have enabled LD₅₀ (lethal dose to 50% of the population) of 0.49 mg. kg.⁻¹ (95%CI 0.29-0.70mg. kg.⁻¹) and LD₉₀ (lethal dose to 90% of the population) of 0.70mg. kg.⁻¹ (95%CI 0.47-0.87mg. kg.⁻¹) to be calculated (E. Spurr unpubl. data). Early field trials indicated that these toxicity levels may be underestimated (Murphy 1997; Dilks 1997). Spurr & Hough (1997) recommend 1mg 1080 per egg, and this dosage rate has recently been confirmed (P. Dilks pers. comm).

Table 5: Summary of trials of 1080 poison deployed in hens' eggs. n = sample size; M=male; F=female; %1080 = $gm\ l^{-1}$

Source	Amount of 1080	Trial Date	N	Result	Comment
Spurr unpubl. data	0.5 mg/kg live weight		2	1 out of 2 stoats survived	Captive trial
Spurr unpubl. data	0.75 mg/kg live weight		7	All died within 12 hrs	Captive trial From this an LD ₅₀ was estimated at 0.49 mg/kg live weight
Spurr unpubl. data	0.3 mg/egg	1994		Reduction in egg take in poison area - see text.	Field trial. At this dosage an average* male eating 1 egg receives 0.94 mg/kg; average* female eating 1 egg receives 1.5 mg/kg
Murphy 1996a (publ. internal DoC report); Dilks 1997	0.6ml of 5.9% 1080 = 35.4mg/egg	1994/1995	6 transmitted 2 M, 4 F	3 died within 7 days; 2 AF wouldn't eat eggs -see text	Field trial. 1080 solution was meant to be 0.05%. Only found on testing solution afterwards.
Murphy 1997a (publ. internal DoC report)	0.5ml of 0.1%1080 =0.5mg/egg	1995/1996	10 transmitted in poison grid	8 died; 5 had 1080 residues in muscle; 2 still alive after trial ended.	Field trial; not known if 1080 residues indicate a lethal or sublethal dose for those that died.
Murphy 1997a	0.5ml of 0.1%1080 =0.5mg/egg	1995/1996	4	1 died, 2 survived; 1 (F) wouldnt eat egg.	Captive trial; 1 (M) that survived ate 2nd egg and died.
Murphy 1997a	1ml of 0.1% 1080 = 1mg/egg	1995/1996	9	All died within a few hours	Captive trial; some had to be helped by puncturing egg.
Dilks 1997 (publ. DoC report)	1ml of 0.1% 1080 = 1mg/egg	1996/1997	17 transmitted	Appeared that the poison was not killing animals quickly	Field trial; Many stoats died of starvation before poison eggs deployed
Miller & Elliot 1997 (publ. DoC report)	1ml of 0.1% 1080 = 1mg/egg	1996/1997	1 transmitted but left area	Indirect evidence only that stoat numbers declined after poisoning	
P. Dilks pers. comm..	1ml of 0.1% 1080 = 1mg/egg	1997/1998	20 transmitted	16 died after consuming eggs; 2 died accidental causes; 1 cause of death unknown; 1 survived	2 ate 2 eggs before dieing; 4M + 2F had to be attracted to tunnels with meat bait, then all but one ate egg after meat; on 5 occasions stoat entered tunnel but did not eat egg

*Average weight of stoats: male = 320 grams, female = 200 grams (Murphy & Dowding 1991).

Field trials must monitor individual stoats by transmitter to determine fates of individuals. This is the only way to know if the poison has had the desired effect (Dilks 1997). Early field trials testing 0.3mg 1080 per egg found a 90% reduction in egg take in the poison area, relative to the non-poison area, after 22 days of poison being available (Spurr 1998), but radio-transmitters were not used to confirm the results that the egg-take indicated. Egg-take alone may not be a reliable index of stoat abundance. A proportion of the population may not eat eggs. For example, 2 adult female stoats would not eat toxic or non-toxic eggs in 1994/95. It is not known whether the high

concentration of 1080 within the eggs was detected by the 2 females, and subsequently made them bait shy, or if they would not have eaten toxic eggs at all. Both stoats had consumed non-toxic eggs prior to poison being deployed. (Murphy 1996). In 1996/97 many stoats were starving (Dilks 1997) yet were not consuming toxic eggs, even though they entered tunnels containing eggs. Although there has been no direct evidence of rats eating, or not eating, poison eggs, rats do enter tunnels and may confound egg-take results Egg-take as an index of abundance (Spurr & Hough 1997) is not reliable.

Miller & Elliot (1997) report a decline in stoat abundance over 2400 hectares after poisoning with 1080 eggs. The decline was estimated from footprint-tracking and egg-take data. However, footprint-tracking data only matched egg-take data after the poison had been deployed, when an average of one egg per week was taken. An estimate of 3-4 stoats within the study area was made on the basis of egg-take data. As discussed above, egg-take data may not be a reliable relative index of abundance. Extrapolating absolute measures of abundance from relative indices must be treated with caution, as absolute abundance cannot be calculated from a relative index (Caughley 1977). Monitoring methods are discussed in Chapter 4.

3.32 Diphacinone

Diphacinone is an anticoagulant poison that prevents blood clotting factors from being made. The poison usually takes 10 - 15 days to kill animals after a lethal dose is consumed (DoC 1997). The recommended dosage of this anticoagulant is 5mg per egg (Spurr & Hough 1997). Indirect evidence (Table 5) suggests that the toxin has the potential to be used successfully to control stoats. Studies to assess the effectiveness of diphacinone are currently underway.

Table 6: Summary of preliminary diphacinone trials in New Zealand. *n* = sample size.

Source	Amount Diphacinone used	Trial date	n	Result	Comment
Dilks 1997		1995/ 1996		7-8 weeks till egg take declined.	No direct measure of control. But no known predation on mohua.
B.Lawrence personal communication (R.D. 1 Queenstown)	3.75 mg/egg	1996	9	No direct evidence that diphacinone controlled population. 10 days after poison deployed 1 st transmited stoat died. 6 of 10 stoats assayed had measurable amounts of diphacinone in liver.	Many stoats in area died of starvation before poison deployed Stoats found dead may not have died from poisoning.
S. Cranwell personal communication (Boundary Stream Scenic Reserve, PO Box 644, Napier)	5 mg/egg	1996/ 1997/ 1998		No direct evidence but footprint tracking rates declined.	Assays found diphacinone in livers of stoats caught in Fenn traps. 1 toxic and 1 non-toxic egg in each tunnel.

3.33 Poison-egg bait-stations

Barriers must be put over the entrance of tunnels, or other stations, to prevent non-target entry and also prevent target species carrying the egg away to cache (Spurr & Hough 1997). One trial used a combination of wooden and metal bars across the entrance way. This was found to be ineffective at preventing stoats from taking eggs away (B. Lawrence pers. comm.). Spurr & Hough (1997) recommend an adapted continental trapping tunnel as a station to place poison eggs in the field, although this may be expensive. Most tunnels can be modified and are probably just as effective. Only one trial has tested stoat preference for poison egg tunnels (Maxwell *et al.* 1997) in which only the blind black Novaflow style "NO EGGZIT" tunnel used by Miller & Elliot (1997) was found to have significantly less eggs taken.

Table 7: Summary of poison tunnel trial in Fiordland. Significance was determined by chi-square at the $\mu=0.05$ level

Source	Trial	N	Result	Comment
Maxwell <i>et al.</i> 1997	Wooden, open vs.	82	1.36 N/S	Sample size is eggs taken overall. Result is eggs taken per 100 corrected tunnel nights. Tunnels were rotated to remove bias from site preference.
	Aluminium, open vs.		1.13 N/S	
	Plastic, open (Phil Thompsons) vs.		1.06 N/S	
	Black novaflow, blind (NOEGGZIT)		0.16	

3.4 Secondary poisoning

Secondary poisoning occurs when predatory species consume prey containing concentrations of poison. Possums (*Trichosurus vulpecula*), rodents and lagomorphs in New Zealand have routinely been targeted with 1080 over the last few decades. Brodifacoum has become a conservation tool useful to eradicate rodent populations on islands (Taylor & Thomas 1989; 1993), the mainland (Innes *et al.* 1995) and more recently for maintenance control of possum populations (pers. obsv.). Monitoring of poison operations has usually been of the target species, and the species being protected. Non-target deaths have been noted but, until recently, only in species susceptible to primary poisoning through direct consumption of poison baits.

Secondary poisoning of mustelids, has been a concern for those countries interested in the conservation of native mustelids for the last two decades (Townsend *et al.* 1984). Many agricultural operations poison rodent pests with first and second generation anticoagulants, and so international research has focused on the secondary effects of these (Godfrey 1985; Hedgal & Colvin 1988; Shore *et al.* 1996; Birks 1998; McDonald *et al.* 1998). Recent research in New Zealand has found 1080 to also have secondary effects (Murphy *et al.* 1998; Gillies & Pierce in press) and it is likely that cholecalciferol may also be capable of producing secondary effects (Wickstrom unpubl. report.)

Secondary poisoning is now recognised as both a threat to some species and a potential tool for multi-control of predatory pests. For those species that display individual aversions, such as stoats to baits or traps, secondary poisoning may be a very important tool as the poison is presented to the predator in their natural prey. There is, however, much that is not known about the mechanisms that govern a secondary poisoning effect.

3.41 Secondary effects from anti-coagulants

Brodifacoum and diphacinone have similar modes of action in that they stop blood-clotting factors from being produced, and may take days or weeks to kill an animal after it has received a lethal dose (DoC 1997). Both are likely to have secondary effects when targeted at primary prey of predators.

Investigations into the secondary effects of brodifacoum in New Zealand started with concerns to native and game species potentially at risk (Godfrey 1985). Predatory birds, such as ruru (*Ninox novaeseelandiae*), and herbivorous and omnivorous birds, such as pukeko (*Porphyrio porphyrio*), are considered most at risk from secondary poisoning or direct cereal bait consumption (Eason & Spurr 1995). Insectivorous birds are considered to be least at risk because brodifacoum is not thought to have any anticoagulant effects on the blood clotting systems of invertebrates although it is not known if insects regularly accumulate detectable levels of brodifacoum (Eason & Spurr 1995).

Consideration of secondary poisoning as a tool for predator control led Alterio (1996) to radio-tag stoats, cats and ferrets throughout a brodifacoum poisoning operation, targeted at rabbits and mice, to determine the effect on individual predators. Stoats, ferrets and cats all died after poisoning and their livers contained brodifacoum residues. Several studies (see Table 8) have followed radio-tagged stoats through poisoning operations with similar results.

However, secondary poisoning by brodifacoum had little observed effect on predator populations when mice were exclusively targeted on Otago coastal grasslands (McKinlay *et al.* 1997; D. Nelson pers. comm.). When rat, possum and mice numbers were very low in kauri forest, continual baiting with brodifacoum did not kill predators, although brodifacoum was subsequently detected in their livers (Gillies & Pierce in press). In both cases, there may have been insufficient prey available for stoats to accumulate lethal levels of poison.

Table 8. Summary of secondary poisoning trials by brodifacoum on stoats. M = male; F = female; tx = transmitted. Assays of brodifacoum residues from liver or other tissue samples are not reported as little is known on how residue levels relate to intake levels, which makes residue results difficult to interpret and easily misunderstood.

Source	Location Habitat Season	Primary Target	n	Secondary Result	Comments
Alterio 1996	Otago Coastal grasslands Winter	Mice Rabbits	2M 1F	All tx stoats in poison area died	Brodifacoum - 20ppm; hand broadcast 7 kg/ha
McKinlay <i>et al.</i> 1997	Otago Coastal grasslands Spring	Mice	—	Trap/catch after op. caught significantly more stoats in non poison area.	Brodifacoum 20ppm; bait stations to mice only; approx 2kg/ha
Alterio, Brown & Moller 1997	Sth Is. Beech forest Su / Au	Mice Rats	9M 2F	All tx stoats died within 9 days of poisoning.	Brodifacoum; hand broadcast 3kg/ha; High mouse density
Brown, Alterio & Moller 1998	Sth. Is. Beech forest Wi / Sp	Rats Possum	8M 2F	All tx stoats died within 50 days	Brodifacoum; Mice at low density. Site A:hand broadcast 3kg/ha SiteB:bait stations 0.32kg/ha.
Alterio & Moller 1998	Sth Is. Podocarp forest Spring	Rats Mice Possum	6 (A) 4 (B)	All tx stoas died in 20-78 days	Brodifacoum, bait stations. Site A - 0.21kg/ha Site B - 0.15kg/ha
Murphy <i>et al.</i> 1998a	Central Nth. Is. Podocarp- hardwood forest Summer - Winter	rats possums	40	31 of 40 stoats captured contained brodifacoum residues.	Only indicates levels in stoats surviving secondary poisoning; Rats contained brodifacoum residues 3 months after poisoning.

However, brodifacoum is known for its persistence in animals. Murphy *et al.* (1998a) report detectable levels of brodifacoum in rats 3 months after the removal of poison baits, although at lesser rates than during the poison operation. This means that live rats are likely to be a continual source of poison for predators. The relationship between the dose of poison ingested, residual traces of brodifacoum retained in tissues, and the significance of this retained dose to the animals coagulation system is poorly understood and likely to include marked individual variation (Hedgal & Colvin 1988). Therefore, caution in interpreting residual results is advisable.

3.42 Secondary effects from 1080

Secondary poisoning of predators has also been identified after 1080 poison operations in Northland (Gillies & Pierce in press) and central North Island (Murphy *et al.* in press) targetted possums and rats. The acuteness of the poison means that secondary poisoning will take effect over a shorter period than anticoagulants.

In Trounson Kauri Park, Northland, 1080 (0.15%) in cereal pellets was distributed by bait station for 18 days in winter, then removed. A number of predators, including one stoat, had radio-transmitters attached and were followed during, and after the poison operation. All of the predators observed died between five and twenty-one days after

the 1080 was put into stations. The stoat died 10 days after the poison was deployed. Residues of 1080 were detected in the skeletal muscle of the dead predators (Gillies & Pierce in press).

Carrot baits, coated with 1080 at two toxic loadings (0.15%,0.08%), were aurally spread in August 1997 over two adjacent areas in the central North Island. Tracking tunnels were used as an index of abundance of both rodents and stoats. Live-trapping was also used as an index of stoat abundance, and 13 stoats (10M, 3F) had radio-transmitters attached. All 13 transmitted stoats died between 2 and 18 days after the poison was spread. Ten of the stoats died within 6 days, 2 that had been out of the area when the poison was dropped were found dead in the area after 7 days, and remaining one was found dead after 18 days. Twelve of the 13 stoats had detectable levels of 1080 in muscle tissue. Most of the stoats (67%) had eaten rats prior to death, although bird, possum and weta were also found in stoat guts (Murphy *et al.* in press).

3.43 Poisoning efficacy

The two studies documenting the secondary effects of 1080 suggest that the routine use of 1080 to control possums and rats may have inadvertently been affecting carnivore populations. However, control operations using 1080, and brodifacoum, have been undertaken in New Zealand for a number of years without any perceived decline in carnivore abundance. However, until recently, there has been no study of carnivore population demographics after poisoning has targeted rodents and possums. It appears the main factors affecting efficacy of secondary poisoning are the relative importance of available prey items in the predators diet, the size of the predominant prey item, the type of poison used and possibly the dosage and rate at which the poison is deployed. Further research is required to determine the optimum levels of prey required to carry the poison to predators, and optimum rates of poison.

Secondary poisoning killed the known resident stoats (3 F, 7 M) in a south Westland podocarp forest in late winter (Alterio & Moller 1998; Alterio & Moller in press). Male stoats were detected by live-trapping between 2 and 12 weeks later and 2 juvenile females were caught in the area 16 weeks after the poison operation. Five of the 10 immigrants settled into the poison area and survived. Further study of the length of time the secondary effect lasts, at differing rates of poison, are needed.

The ecological interactions involved as a consequence of suppressing one of the elements in an ecosystem are complex and may take decades to fully understand (Yodzis 1988). Introducing a further confounding factor of secondary poisoning increases the complexity. Scientists and managers need to be aware that the curbing of

one pest species may not have the desired advantage for the species being protected. For example, Murphy *et al.* (1998b) report an increase in bird consumption by stoats after rats had been effectively poisoned. Other scenarios, such as increases in weasels as stoats and rats decrease and mice increase, also need to be tested to help understand the wider implications of control measures.

3.5 Other methods of control and damage prevention

3.51 Stoat and pest-proof fences

Fences to exclude pest species are not a new idea. Deer (Fam. Cervidae) exclosures, set up to determine effects of ungulate browsers, have been used extensively in the past and are still being utilised today (pers obsv.). A possum proof fence has been erected on Cape Brett, Northland, to prevent further damage to pohutakawa (*Metrosideros excelsa*) (Project Crimson 1995).

A predator-resistant fence was built around Burwood Bush Takahe Unit near Te Anau (Avis & Roberts 1994). Significantly fewer predators were caught inside the exclosure than outside throughout 8 years (Numata *unpubl. data*). Although requiring a high degree of maintenance (Avis & Roberts 1994), the fence effectively excluded predators and, as a result, there has been no predation on takahe within the fence.

Karori Wildlife Sanctuary Trust have been the first to develop a fence designed to exclude all introduced mammalian predators, including stoats. The fence consists of a wall component, a hat component to stop climbers, and a skirt component to preclude diggers entering underneath the fence. There have been many trials involved in the ultimate design of the fence. The ultimate trial will be the fences' ability to exclude all mammalian pests, and the Trust's ability to detect a breach in the fence. Construction of the fence is currently under way (J. Lynch pers. comm.). The fence is fully described in Fuller & Gorman (1997).

3.52 Vegetation buffers

Natural vegetation was noted as providing a buffer zone between predators and upland nesting ducks in south Dakota (Duerbert & Kantrud 1974). Areas with tall, dense, rank cover produced many more ducks than areas without cover, even when predators were reduced in such areas (Duerbert & Kantrud 1974). Skilful habitat manipulation was advocated as an alternative to direct predator control. There were however, other factors, such as habitat type, influencing the results observed. Nevertheless, vegetative buffering was adopted by scientists and managers responsible for Yellow-eyed penguin (*Megadyptes antipodes*) in coastal Otago (DoC 1989) in the hope that the numbers of rabbits living in the area would be reduced, and so reduce the

number of predators. Areas of grazed grassland adjacent to yellow-eyed penguin breeding colonies were procured and allowed to acquire tall, dense and rank cover. Subsequent studies revealed that the buffers were, in fact, harbouring rodent species, and were therefore attracting predatory species, rather than acting as a buffer (see Moller *et al.* 1995). Vegetation alone is no longer seen as providing a buffer against predation (Moller *et al.* 1995).

3.53 Repellents

Repellents may be useful to discourage stoats, and other predators, from a particular area at a particular time. For instance, if the aim is to protect known kaka or kiwi nests from predation, repellents may be used in conjunction with ring trapping. Finding a substance, sound or sight that consistently repels all stoats may prove a challenge. Some stoats may have the desired response, while others may display only curiosity, caution or (if tested against retrieving a prey item) hunger. Irritants, such as pepper may warrant investigation.

Two ultrasonic devices³ were tested for repellent properties. Captive stoats showed some hesitancy in approaching a dead food item within the ultrasonic field (Spurr 1997). However, in all cases (n=6) hunger overcame any hesitancy caused by the ultrasonic frequency, and one stoat approached the food item without hesitancy (Spurr 1997). The hearing range of least weasels (*Mustela nivalis*) was tested in the United States, and found to be best within a 1-16 kHz range, which follows the range common for carnivores (Heffner & Heffner 1988). Both ultrasonic devices were set at low levels: the Transonic® ESP at 10 - 50 kHz and the Yardgard® at low (frequency unspecified) (Spurr 1997). It appears that ultra-sonic fields did not repel stoats.

In field trials of slow-release synthetic scent lure for mustelids, ferrets, particularly males, were attracted to one of the scents (PT lure, 2propylthietane), although stoats were not (Clapperton *et al.* 1994; Dilks *et al.* 1996). The scent lures were imitations of secretions from both ferrets and stoats. However, a synthetic ferret-only anal sac secretion may have the potential to repel stoats. Stoats avoid areas that ferrets inhabit (Pierce 1987; Ratz 1997b) and there is anecdotal evidence of trap avoidance by stoats, to traps that have caught ferrets (A. Elbers pers. comm.; B. McKinlay pers. comm.). Ferret scent as a repellent requires investigation.

Recent attempts to attract stoats toward trap lines with a scent trail of refined fish oil were ineffective (Rudolph 1998). An inverse relationship developed between scent

³Transonic® ESP & Yardgard® (Weitech Inc., U.S.A.)

trails and trap capture rates. Fish oil may also be a potential repellent that warrants further investigation.

3.54 Damage prevention - predator recognition and aversion

New Zealand's avifauna evolved without mammalian terrestrial predators and therefore without related predator recognition and aversion behaviours. Maloney & McLean (1995) suggest that birds currently surviving well on mainland New Zealand in the presence of mammalian predators have learned predator response.

The hypothesis was tested by the response of experienced (mainland) and naïve (island) New Zealand robins (*Petroica australis*) to a model predator (stoat) and a control box. Response behaviours were compared with normal behaviour (Maloney & McLean 1995). Experienced robins responded more strongly to the stoat model than the control; naïve robins had a weak response to both the stoat model and the control. The authors also tested the naïve robins' ability to learn to respond with alarm to a stoat model. Naïve robins did learn to respond with alarm to the model after one-event learning (Maloney & McLean 1995). The differences in response between takahe and pukeko were also tested in the same manner (Bunin & Jamieson 1996). Pukeko displayed heightened signs of alertness to a model stoat. Takahe chicks, cross-fostered to pukeko parents, also showed a stronger response than normal takahe chicks. However, takahe chicks show a high degree of individual variation, so the two cross-fostered chicks in this study may have always displayed a heightened response.

The technique of raising the level of predator recognition and aversion through human-induced learning, or through cross-fostering, may be of value in reintroduction programs from island to mainland.

3.55 Fertility and biological control.

Investigation into methods of controlling stoats other than trapping and poisoning, which require ongoing maintenance and financial support, may be the best long-term solution. The advantage of a good fertility or bio-control is that it would affect a high percent of the population, be humane and host specific. The biggest disadvantage is the expense of developing such controls, and the inherent risks of releasing an intractable organism (Moller 1989). This section reviews some of the options.

Fertility control should be aimed at the most vulnerable period of a stoat's life-history (Norbury in prep.). This appears to be the period during which implantation of blastocysts is delayed, which is usually from about November to about July (King & Moors 1979). This leaves a period of nine months in which to interfere with pregnancy

before foetuses are formed. The current options for achieving this sort of control are through chemosterilants and immunosterilants. Many have been developed specifically for other carnivores, and some show potential. These options are reviewed by Norbury (in prep.).

The options for bio-control are limited at present, and do not show as much potential as fertility control. Some potential agents could perhaps be better considered as carriers for more deleterious organisms. Stoats throughout the world are known to carry a parasite, *Skrjabingylus nasicola*. This large, red, worm-like nematode inhabits the frontal and nasal passages of mustelids. This causes distortion and damage to the skull, resulting in pressure on the brain (King & Moody 1982c). There is little evidence in New Zealand to suggest that the parasite affects condition of individual stoats, or limits populations (King 1991). Of stoat carcasses infected with the parasite, 3 out of 7 within geographic area comparisons, showed smaller body size but this was not significantly different (King & Moody 1982c). Parasites can reduce survival and productivity in some bird species. Grouse (*Lagopus lagopus scoticus*) infected with nematodal parasites were more vulnerable to predation (Dobson & Hudson 1994). While parasites may not limit stoat populations (King 1991), they may make stoats more vulnerable to predation and trapping, which is, after all, human predation. A national database of stoat autopsies collating infestation levels of nematodes and cause of death i.e. trapping, poisoning or road kill, could provide information on the current range and rate of infestation. Autopsies of 2522 stoats described by King & Moody (1982c) found a mean level of 10% infestation in stoats over 6 months old. The highest incidence was in areas of beech forest and scrub-grasslands. Further autopsies comparing infestations in Fiordland and Craigieburn found much higher rates, of up to 30%, in the Craigieburn area (King 1991). However, none of the work compared infestation rates between trapped stoats and those dead of other causes. If parasitic infestation was rendering stoats more 'trappable', then it may be worth while actively spreading the nematode during winter, when stoats seem to be more susceptible to infection (Hansson 1974).

Members of the mustelid family, including stoats, are susceptible to canine distemper. This may deserve investigation as a potential tool for bio-control, although the side-effects on non-target species, such as domestic dogs, would have to be considered. The advantage of this disease is that it is already endemic within New Zealand (Norbury in prep.).

Ragg *et al.* (1995) found bovine tuberculosis (TB; *Mycobacterium bovis*) in stoats. Although sample sizes were too small to determine prevalence ($n=62$; $0.04 < \text{mean prevalence} < 8.95$), there may be some worth in further investigations. For instance,

ferrets have recently been accepted as a vector of TB to livestock (Ragg & Walker 1996). In areas with a high prevalence of TB and a low abundance of ferrets, do stoats have a higher prevalence of TB?

Research into fertility and bio-controls could easily eat up millions of dollars of funding without any guarantee that there will be any positive outcome. Nor is public acceptance guaranteed. Delivery of any chemical or immune-response organism is still reliant on bait that attracts a high percentage of the population, even in low densities. Norbury (in prep.) considers the most important tool to use, before investing in fertility or bio-control options, is population modelling. A good model could determine the levels of sterilisation or mortality needed to be an effective control strategy. If those levels were not realistically achievable, there may be little point continuing with research. However, there is still much to be learnt about the stoat's social organisation, dominance relationships, compensatory responses and potential to develop resistance quickly, that would need to be incorporated into an effective model (Norbury in prep.)

While fertility and bio-control may be the best long-term solution, we may not have a long time to find it. Species such as kaka and kiwi have already suffered local extinctions on the mainland (Wilson *et al.* 1998; J. McLennan pers. comm.) and may not tolerate stoat predation for much longer. However, as technology develops, there may be the opportunity for integrated management of current with new techniques.

4. Monitoring

Monitoring of populations, as indices of abundance, are important for control operations to determine pre and post control densities, and therefore operational success. The status of pest populations in relation to environmental factors such as climate, food supply and reproductive state; and densities in relation to levels of predation on a specific resource, are also important to determine timing of control operations and target densities.

This means both relative (density of one population relative to another) and absolute (number of animals per unit of area) measures of abundance are crucial for future research and management of stoats. Relative indices are needed to answer questions framed in a relative way, such as, 'do stoat densities decrease when mouse densities decrease'? Absolute indices are needed to answer questions such as 'What proportion of a stoat population will enter a tunnel?' However, because of marked individual variation, stoats have proven difficult to monitor in any consistent and reliable way. Most of the information presented in this review has been gained by autopsy or radio-tracking, where the population is known, often backed up by indices of abundance, which may or may not agree with more reliable methods of gathering data. A standard protocol for relative indexing of stoat abundance are being developed. Consistency is of the utmost importance so that when results from different locations or seasons are compared, the same monitoring regime has been used.

4.1 Relative density index : Trap/catch

The number of animals caught, per number of trap nights set, is a common way of indexing small mammals and rodents. Both live-traps and kill traps can be used to obtain this index, although kill trapping consistently removes part of the population being sampled, which may disturb the population. Trapping conditions, efficiency, and gear should all be standardized (Caughley 1977). Trap nights available are usually corrected for the number of sprung traps in the manner described by Nelson & Clark (1973).

However in the past in New Zealand, traps have been set at different spacings, covered very different areas, set with different baits, or have had other confounding variables which make interpretation of results misleading (Lawrence 1998). Calibration of trapping indices relative to absolute density (Caughley 1977; Cross *et al.* 1998) are urgently needed if trap/catch results are to be reliably interpreted. Calibration may change with season and habitat (Alterio *et al.* subm.) and therefore calibrations may

have to be repeated with season and habitat, which could be expensive. A preliminary calibration of trap/catch as a relative index of ferret abundance was conducted in Otago in 1997, which confirmed the use of trap/catch as a reliable index of ferret abundance (Cross *et al.* 1998).

4.2 Relative density indices : Tracking tunnels

Footprint tracking data is obtained by placing an ink, or chemical, tray in the middle of two sheets of tracking paper, underneath a tunnel about 600mm long (Moors 1978; King & Edgar 1977). As long as rain is excluded, tunnels can be wooden, plastic, aluminium or corrugated plastic. A bait is sometimes placed in the ink tray. As animals come to investigate either the bait or the tunnel, as long as the animal steps in the ink tray, indelible footprints are left on paper. The papers can then be collected and changed as frequently as needed, and the data from footprints interpreted at a later date (King & Edgar 1977; King *et al.* 1994; Ratz 1997b)

Tracking tunnels also require standardisation and calibration to determine if tracking rates, which are usually expressed as a percentage of tunnels tracked by a species, are comparable between habitat and season, and reflect real changes in stoat abundance. There have been conflicting results obtained from several studies that have used tracking rates of stoats in conjunction with radio-tracking or live-trapping. Problems encountered with tracking tunnels have included learned behaviour by stoats that the tunnel contains food, or is fun to run through, inducing the animal to return again and again to one tunnel, or finding other tunnels and tracking them too (Murphy, Robbins & Clapperton in prep.; C. Gillies pers. comm.). If tunnels are un-baited, then curiosity is the behaviour relied upon to entice a stoat into a tunnel, which may vary individually. When tunnels are baited, hunger may determine, and confound, stoat tracking rates, particularly when large fluctuations in prey abundance occur (Lawrence 1998). Non-target species, such as possums and hedgehogs, are often attracted to the tunnels and may either interfere with the tunnel itself or, as with hedgehogs, leave large footprints that can obscure other species tracks on the paper (pers. obsv.).

One preliminary study used infra-red video cameras, in repeated alternative positions, to compare presence/absence data obtained with un-baited tracking tunnels (Lawrence & Loh 1997). The camera and tunnel agreed on 8 out of 12 positions. Of the 4 positions that disagreed, the tracking tunnels recorded 2 animals that the cameras did not, and conversely, the cameras recorded 2 animals that the tracking tunnels did not. The authors note, however, that the trial was undertaken

in a year of low stoat density, when they did not expect large variation between curiosity and hunger (Lawrence & Loh 1997).

Clapperton *et al.* (subm.) report a significant increase in stoat tracking rates after real anal-sac secretions were placed in tunnels. Rabbit meat placed inside tracking tunnels also significantly increased stoat tracking rates (Murphy, Robbins & Clapperton in prep.). Rat and mouse tracking rates did not appear to be significantly affected by the presence of bait, lure or stoats using the tunnels, in either study. However, in the meat baited tunnels, mustelid tracking rates increased with each successive set (Murphy, Robbins & Clapperton in prep.), which may indicate a real change in abundance over time, or may just reflect a learned response to food by stoats. This learned response could potentially affect future tracking periods.

Stoat tracking rates increased for the first four days of a tracking period, then decreased, which may indicate that a four day period is the optimum time period that tracking tunnels should be set (Murphy, E.; Robbins, L. & Clapperton, K. *unpubl. data*). However, Brown *et al.* (1998) baited tracking tunnels for 3 consecutive nights on 3 occasions and found that the tracking lines did not accurately record the decline in population after a poisoning operation had secondary effects on the resident stoats, measured by radio-tracking. The authors suggest that the tracking recorded after the death of residents may have been immigrant stoats, and that one or two stoats could potentially track all the tunnels at one site. Brown & Miller (1998) report very low tracking rates, at two sites, for the first two and four weeks respectively. They advise data from the first three weeks of set tunnels should not be used in estimating population changes from control regimes. However, increased tracking rates could be from resident, transient or immigrant stoats learning to track tunnels.

Murphy *et al.* (in press) baited tracking tunnels for two consecutive nights, every 4-6 weeks throughout a poison operation, and report a significant correlation between live-trapping and tracking indices. On occasion however, the live-traps indicated the presence of stoats when the tunnels indicated absence; and the tunnels had over 50% tracked but only 2 stoats were live-trapped. The authors conclude that despite these discrepancies, the tunnels appeared to give a good indication of what was happening to stoat abundance.

Because of such discrepancies, and sometimes patchy distribution of stoats, replication within the area being sampled is necessary to obtain meaningful results. Brown & Miller (1998) tested the power of tracking tunnels to detect a change in stoat

density over a large area (>2000 ha). They collected data from tunnels placed at differing spaces, and used a simulation model to assess monitoring design. Stations that were 500m apart had similar tracking rates (positive correlation), which may be expected if the same stoat were running through adjacent tunnels. The authors conclude that tracking tunnel sites should be 1000m apart to ensure independence of data, and multiple stations at a site would increase the chances of a stoat encountering a tunnel, and therefore being detected. However, in this design tunnels were baited and left out for several weeks. The same stoat tracking the same tunnel week after week could be a potential problem. The design recommended by Brown & Miller (1998) is suited for large areas but could possibly adapted to smaller areas.

4.3 Absolute density

Determining target densities of stoats per set area, to protect species over a vulnerable period, has been difficult to achieve without a reliable method of measuring stoat density, either relative or absolute. However, a model has been used to determine critical numbers of stoats present in a forest ecosystem, that will allow kiwi populations to remain stable. The model predicted a critical number of less than 2 stoats per km² (J. McLennan pers. comm.).

Alterio *et al.* (subm.) estimated absolute density of stoats in a South Island beech forest. Using a capture-mark-recapture design, Edgar traps were placed in circular lines, at 150m intervals, for 14 days in summer (Jan./Feb.) and 11 days in winter/spring (Aug./Sep.). The summer followed a beech seed fall the previous autumn, i.e. 8-9 months later, and the winter, correspondingly, 15-16 months later. Population was estimated for each period with a computer program CAPTURE, which assumes closed population, i.e. no births, deaths, immigration or emigration, over the trapping period. The population estimate is then divided by the effective trapping area to give absolute density. Absolute densities were reported as 4.2 stoats km² (95% C. I., 2.9-7.7 stoats km²) for the summer period and 2.5 stoats km² (95% C. I., 2.1-3.5 stoats km²) for the winter period.

Effective trapping area was calculated by increasing each circular trapline with a strip the average radius of a stoats range, for that time of year and stage of the beech seed cycle. The average radius for the summer period was calculated from stoats studied in a similar habitat but from January to May and over 300km away. The winter period was calculated from a study in the same year and area (Brown *et al.* 1998) but over springtime, when home ranges and spatial patterns can change (Erlinge 1977; Debrot & Mermod 1983).

Absolute density calculations could be imprecise if based on inaccurate data. The important variable of effective trapping area needs to be closely correlated with the time period in which the densities are estimated, when calculating absolute density . However, Alterio *et al.* (subm.) have been the first to publish an attempt at estimating absolute abundance of stoats in New Zealand, and determining reliability of trapping rates as a relative abundance. Further studies of this nature are long over due.

5. Conclusions and Recommendations

5.1 Current control methods

Monitoring of species under direct threat of predation by stoats has shown that controlling stoat populations can increase productivity and survival rates in the threatened species. For example, trapping of stoats in Waikaremoana has increased survival rates of kiwi from 7% to 58% (J. McLennan pers. comm.).

Stoats are intelligent individuals with differing responses and behaviours. At present, and as technology improves, an integrated range of techniques, that takes into account individual variation, should be employed.

Continual or pulsed kill trapping is still, at present, the only proven and safe method for controlling stoat populations. Further studies on distribution patterns, which at present appear to be patchy in some habitats and random in others, as well as documentation of microhabitat use and trap or tunnel site preference will enable better use of the available trapping resource. An effective bait appears to be more important than tunnel type, and pre-baiting may prove worthwhile. New baits and lures, particularly long-life ones, should be an immediate priority for research.

Development of a monitoring protocol is long overdue and requires urgent attention.

5.2 Conservation management implications

Calculation of re-invasion rates will allow more accurate timing of both trapping and future poisoning operations, again enabling more cost-effective control. Direct poisoning requires further research into efficacy, different baits to carry poisons and mustelid specific poisons. Secondary poisoning may be a potential tool for multi-predator control, but long term effects need to be studied.

Current control methodology and research, is however, labour intensive, and therefore costly. A co-ordinated approach involving all control operations in refining trapping and poisoning techniques would ensure that adequate replication of trials are achieved, and that unnecessary trials are not undertaken. A co-ordinated approach also ensures consistency

As bigger and bigger areas are managed for conservation threats and require stoat controlled, opportunities for integrated control methods and integrated pest management (Parkes & Nugent 1995) will arise. Integrated control could include accurately timed direct and secondary poisoning or fertility control backed up by

trapping, Integrated pest management is already taking place in mainland islands, areas aiming to restore mainland ecosystems. However, long term effects on population demographics are poorly understood.

The opportunity for "adaptive management" (Walters & Holling 1990) is large and should not be ignored. Adaptive management is not just adapting management regimes to new knowledge, but includes the gain of reliable knowledge (Romsburg 1981) within the management aims. This may discourage conservation managers, as resources are limited, and additional demands means less effort is placed in actual control. However, the long-term benefits of gaining new insights and knowledge outweigh the short-term costs. Adaptive management has been successful in helping to restore North Island kokako (*Callaeas cinerea wilsoni*) populations (Innes *et al.* 1999).

6. Priorities for future research

6.1 Current control operations

Every control operation has the potential to yield information that can confirm or add to what is already known, or reveal something new that can help advance control techniques. However, control operations must ensure that sampling design will allow reliable results to be obtained. There is little point in testing four variables when it is likely that only 20 stoats will be caught over the trial period. It is far more robust to test one variable to ensure that useful information will be gained.

Priorities for research on refining current stoat control techniques include:

- further trials with conibear traps
- further efforts to document where stoats are caught in different habitats and isolation of the elements that influence tunnel site preference
- a more efficient way of checking traps
- further testing of baits in different habitats comparing seasonal and sexual acceptance
- formal testing of the theory that human scent on a trap site reduces catch rate
- layout and spacing of traps over small and large areas
- a robust trial of the plastic tunnel covers (Phil Thompson's) with wooden tunnels

6.2 Priorities for future research

More formal research should focus on short, medium and long term solutions. Listed in order of priority, these include:

SHORT TERM - Immediate priority

- calibrate tracking tunnels and trap catch as a relative index and develop a protocol
- determine if control of stoats in the autumn or winter before a predicted stoat irruption defers the irruption
- advancement of the anal-sac scent lure
- investigate into olfactory lures, including bird odours
- ascertain the data on reinvasion rates to enable a re-invasion model to be designed
- confirm diet shift after rodent poisoning in habitats other than North Island podocarp-hardwood

MEDIUM TERM - Important and urgent.

- find a long lasting substance to which different baits or lures can be added.
- improve interpretation of anti-coagulant residues in tissue samples
- determine how long secondary poisoning effects last
- investigate cholecalciferol as a poison for stoats
- determine community response to one off control in different habitats

- investigate alternative toxins for stoat control that may be more specific
- LONG TERM- Important but not urgent.
- Intensive radio-transmitting through a beech seedfall event and the following two years
 - determining if sub-lethal poisoning and parasitic nematode infestation renders stoats more trappable, through a national database of autopsies
 - determine dynamics and demographics of stoats when density has been reduced - do stoats reinhabit the area at greater density ?
 - determine relationships to other members of the pest community eg. mice, rats, weasels, ferrets, cats
 - investigate the most promising fertility control options
 - investigate repellent properties of irritants, ferret scent and fish-oil

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