Risk assessment of stoat control methods for New Zealand

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John Parkes and Elaine Murphy

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John Parkes[1] and Elaine Murphy[2]

[1]Landcare Research, PO Box 69, Lincoln 8152, New Zealand
email: parkesj@landcareresearch.co.nz
[2]Department of Conservation, PO Box 13-049, Christchurch, New Zealand

ABSTRACT

Optimal application of a pest control method requires the paraphernalia of the technique (e.g. the trap, toxin, bait), its acceptable and safe application (e.g. humane use, environmental safety, target specificity), and knowledge of how to apply it strategically (e.g. where, when, how often, how intensively). We review current and potential stoat control methods to identify where the main constraints and risks on their optimal use lie, and suggest ways to overcome these where possible. For traps, the main constraints are an incomplete knowledge of their strategic application, and the main risk is that none, at the time of writing, meet draft animal welfare standards For baits and lures, the main constraints are the lack of a bait designed to meet all managers' needs, either as a lure to traps or as something all stoats will eat when presented by various methods. For toxins, the main constraint is that currently none are registered for stoat control, and the main risks are the usual concerns about non-target species exposure and public acceptability common to all toxins. For classical biological control, the main risk is the lack of public acceptability of some possible agents (e.g. canine distemper), but the technique is more seriously constrained by the lack of any putative agent that would overcome potentially low transmission rates among non-social animals such as stoats. For immunocontraception, the main risk is that no suitable agent for stoats will be found, and the main constraints are the expense and time needed to identify and test agents and to develop a suitable bait or live vector to deliver the agent. Control of the primary prey of stoats such as rodents is as difficult as stoat control itself, but the use of immunocontraception against species such as mice (the target of current Australian research) might reduce stoat densities in beech forest in mast years. The risks of prey-switching by the remaining stoats would need to be considered before this strategy was adopted. 'Boutique' control methods such as the use of dogs and fencing are, by their nature, of limited use—but still of importance.

Keywords: Stoat, *Mustela erminea*, control methods, risks, constraints.

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1. Introduction

Stoats are arguably the worst pest among the suite of introduced predators that threaten native vertebrates in New Zealand (King et al. 2001). Unfortunately, they are difficult animals to control for several reasons. First, they have a flexible, r-strategy life history (King 1990). In some habitats, such as beech forest, stoats' population density and dynamics change significantly as their rodent primary prey densities fluctuate with changing food supplies (King 1983; Murphy & Dowding 1995). However, in other habitats this link between rodent and stoat abundance is less consistent, and it is not clear that the same mechanisms (a numerical response to prey abundance) that drive the beech habitat relationships operate (King et al. 2001). The implications of these changes in stoat population dynamics are that they can have both periodic but acute impacts on prey populations when at high densities (e.g. on mohua, *Mohoua ochrocephala*; O'Donnell et al. 1996), as well as chronic impacts on some particularly vulnerable prey species even when at low densities (e.g. on kiwi chicks, *Apteryx* spp.; McLennan et al. 1996). Therefore, targeting control to periods of maximum impact is difficult, even when such periods can be predicted. For example, control during a stoat irruption has to overcome the large natural rate of increase during the irruption, while control during low-density phases has to expend large and repeated effort for little result in terms of dead stoats.

Most current control techniques require intensive effort at a high cost per hectare to achieve effective control. With limited departmental budgets, this means only a small proportion of the total problem caused by stoats can be treated, particularly given that the uncertainties about the optimal time to intervene lead managers to take a precautionary approach and perhaps intervene when they do not have to do so. Finally, stoats are entirely a conservation pest. This is unlike some other exotic predators in New Zealand (e.g. possums, *Trichosurus vulpecula*, and ferrets, *Mustela furo*, which are extensively controlled by other agencies as vectors of bovine tuberculosis, thereby providing some incidental benefit to native prey.

There is strong evidence that stoats are a critical factor in the decline of several iconic bird species such as kiwi (McLennan et al. 1996), kaka (*Nestor meridionalis*; Wilson et al. 1998; Moorhouse et al. 2003), mohua (O'Donnell et al. 1996) and yellow-eyed penguin (*Megadyptes antipodes*; Moller et al. 1995). Despite the need, current control tactics[1] and strategies are not adequate to deal with the scale of the problem. In 1999, these inadequacies prompted the NZ Government to fund a 5-year Stoat Research Programme, totalling NZ$6.6 million, managed by The Department of Conservation (DOC). This programme links in with other projects funded by the Public Good Science Fund in Landcare Research's 'Mitigating Mammalian Pest Impacts' programme. Some of these projects aim at improving the efficacy and efficiency of current control methods and beginning development of new control tools, and it is these that we review in this report.

[1] A glossary is provided in Appendix 1.

2. Objectives

The objectives of this study were to identify the constraints, risks and benefits of current and potential stoat control methods and indicate ways to mitigate risk where possible, by:

- Summarising current and potential stoat control methods
- Categorising the advantages and disadvantages in the ways these methods might be employed
- Identifying the technical and social risks of failure and consequences of use and, where possible, suggesting ways to mitigate them

3. Methods

There is a large amount of dispersed information on control methods for stoats from both operational and research sources. To put this into some coherent form that addresses the objectives of the report we attempted to answer the following questions:

- How is each control technique currently used, or potentially used, and what are the advantages of the method, particularly relative to other methods?
- What is lacking or sub-optimal for each method that constrains managers from achieving a substantial increase (say by an order of magnitude) in efficacy?
- What are the contingent risks that might affect each method's use in the future?
- Can these constraints and risks be overcome by current or future research and management, or is what we have about as good as it gets for the method?

We reviewed published New Zealand studies that cast light on the constraints and risks we had identified as important. We have not commented on research-in-progress, except to note from the objectives of such research whether they are attempting to address the key issues we raise.

4. Results

4.1 KILL TRAPS

4.1.1 Current uses and advantages

Kill-trapping is currently the main stoat control method used by DOC covering c. 100 000 ha in 51 mainland operations (Christie et al. 2003). The components of trapping (Table 1) can generally be partitioned into the physical aspects (generally with tactical or logistical solutions to improve them), and usage

TABLE 1. COMPONENTS OF STOAT TRAPPING AND THE MAIN CONSTRAINTS AND RISKS.

COMPONENT OF TRAPPING	MAIN CONSTRAINTS	MAIN RISKS
Trap type	Catch effectiveness and cost to buy and use	Does not meet the required humane standards
Tunnel	Design to lessen non-target risks	Increasing non-target protection may decrease attractiveness to stoats
Lures	Detection distance and attractiveness	Increased attraction of non-targets
Lure replacement frequency	Lure life and consequent cost of visits	Lure may act as a deterrent if it is too old/rotten
Trap densities/layout	Lack of data to develop best strategy for all situations Likely to vary, depending on size of area to be trapped and species to be protected	May vary significantly between areas so control has to be tailored for each site
Seasonal use	Lack of data to develop best strategy	Mis-timed control may not protect prey
Trap visit frequency	Lack of data to develop best strategy	Trap saturation
When to set in relation to stoat density	Lack of data to develop best strategy	Mis-timed control may have no effect on stoat dynamics

aspects (generally with strategic solutions). However, no combination of improvements to trap design or usage is likely to increase the efficacy of the technique by the order of magnitude sought in this review.

Generally two Fenn traps (either Mk4 or Mk6) are set either end of a tunnel, usually with an egg or some other lure placed between them to attract stoats into the tunnel. The tunnel is largely to protect the lure from non-target animals and to keep them away from the traps. Fresh eggs are the most commonly used lure, but many others have been tried e.g. freeze-dried rats and mice, fresh meat or fish (Brown 2003). Trap lines are often set around the boundary of the operational area and at various configurations throughout the area, with spacings between traps varying from 25 m to 300 m, with 200 m spacing most common, giving densities of c.15 traps/100 ha—but this varies greatly (Brown 2003; Christie et al. 2003). Traps are sometimes operated throughout the year, but in most operations they are set during the breeding season of the birds being targeted for protection (often from spring through to autumn). On the New Zealand mainland, traps are generally checked weekly or fortnightly over summer, and monthly over winter (Brown 2003). On some islands in Fiordland, the traps are only checked 6-monthly (M. Willans, DOC, Te Anau, pers. comm.) Annual costs of between NZ$7 and NZ$139 per hectare have been quoted, but as no standard accounting of the activities is included, this means that we cannot be sure of the costs (Brown 2003).

The advantages of traps are that they are a proven technique that can reduce stoat numbers sufficiently to protect native biota, e.g. in mainland islands (Saunders 2000; Gillies et al. 2003), with minimal adverse affects on non-target species, or public opposition (Fitzgerald et al. 2002). A survey of usage has been summarised for most sites where trapping has been used (Christie et al. 2003) and in more detail for 15 sites (Brown 2003).

4.1.2 Constraints

The physical components of trapping (traps, tunnels, and lures) can all be manipulated to increase efficiencies a little, but most have fixed costs that are unlikely to decrease substantially by changing one or more of the components. The main constraint on the more effective use of traps is how to apply them optimally in space and time during various phases of a stoat irruptive cycle, i.e. an optimal strategy (Table 1). This strategy could change depending on the species to be protected, topography and the size of area to be controlled.

4.1.3 Risks

The main risk in the use of traps is that the most commonly used ones (Fenn Mk 4 and Mk6) do not meet the National Animal Welfare Advisory Committee (NAWAC) draft guidelines for humaneness (Warburton et al. 2002). This risk is not immediate and is contingent on NAWAC deciding to recommend that inhumane traps should be banned—which they are less likely to do immediately if they can see attempts being made to overcome the problems[2].

4.1.4 Ways to overcome constraints and risks

The physical constraints on traps, tunnels and lures are all being addressed by research on developing new traps and on improved lures (Table 2). The Department also has many stoat control operations based on the use of traps in which managers change the physical components of control in a learn-by-doing approach. The weakness of the current assessment of trapping is that all operational and research reports we reviewed lacked measures of one or more of the vital parameters (e.g. effort, costs, percentage kill, proportion of escapes) needed to obtain unequivocal comparisons in outcomes over time, let alone between operations. Faster progress could be made if there was better operational reporting. The Department is setting up a system designed to do this—Pestlink—which will allow for more robust comparisons in the near future.

Tunnel type

Tunnels to protect lures and restrict some non-target access to the traps vary in construction material and design. The results of trials to identify the best tunnel are sometimes contradictory and may reflect individual preferences by stoats in different habitat types.

Dilks et al. (1996) showed no difference in effectiveness between wooden tunnels with and without wooden bases or between single-entrance and run-through tunnels. Maxwell et al. (1997) trialled four tunnel types in the Eglinton Valley in 1997, showing only a clear disadvantage in using black Novaflow tunnels with one opening; wooden, aluminium and plastic Philproof tunnels open at both ends attracted more stoats. DOC compared trapping success in 35 paired sets using wooden and aluminium tunnels in the Catlins Forest in 1993, and found that all seven stoats caught were trapped in the wooden tunnels (data quoted in Spurr & Hough 1994). A trial to compare the behaviour of stoats towards wooden and aluminium tunnels (baited with eggs or day-old chicks and without traps) showed no effect of tunnel type—although only two stoats were

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2 Since this report was written, three stoat traps have met draft animal welfare standards.

TABLE 2. RECENT RESEARCH ON STOAT TRAPS[1] ADDRESSING CONSTRAINTS OR RISKS TO THEIR USE.

RESEARCH PROJECT	CONSTRAINT/RISK (SEE TABLE 1)	KEY RESULTS FROM COMPLETED RESEARCH[2]	REFERENCE
Automatic, multiple-kill trap	New trap: efficiency with multiple kills	In progress	Ian Domigan pers. comm.
A new trap for stoat control	New trap, efficiency and humaneness	Met NAWAC standards	Domigan in Murphy & Fechney (2003)
Gotcha electronic trap	New trap: efficiency and humaneness	No final product	Agnew in DOC (2001)
Self-resetting mustelid eradicator	New trap: efficiency and humaneness	No final product	Greenall in Murphy & Fechney (2003)
Production of an alternative kill-trap for stoats	New trap: efficiency and humaneness	Didn't meet NAWAC standards	Waddington in DOC (2002)
Evaluation of traps and development of Victor kill-trap	New trap: efficiency and humaneness	Didn't meet NAWAC standards	Thomas in Murphy & Fechney (2003)
Evaluation of prototype Victor kill-trap and Fenns	Humaneness	Neither Fenns nor the Victor kill-trap are humane	Warburton et al. (2002)
Comparison of stoat trapping set designs	Cost, efficacy	In progress	Burns in Murphy & Fechney (2003)
Stoat trap tunnels	Cost, efficacy of 6 types	No significant differences	Maxwell et al. (1997)
Stoat trap tunnels	Cost, efficacy	Mesh and plastic covers cost $7.50 each	Beaven (1998)
Tunnel design	Efficacy of 2 types	No differences	Dilks et al. (1996)
Attractiveness and longevity of lures for traps	Efficacy of traps with lures	Meat more attractive than eggs In progress (June 2003)	Clapperton in Murphy Fechney (2003)
Developing a multi-sensory bait/ lure system for stoats	Lures for traps (but also palatability and acceptance)	In progress	Clapperton in Murphy & Fechney (2003)
Meat and rodent-scented lures	Lures for traps	Meat lures were better than rodent scent	Montague (2002)
Odour to attract stoats	Lures for traps	4 of 19 odours attractive	Spurr (1999a)
Unrestrained mice as lures	Lures for traps	Too few stoats caught to tell	McLennan (1998)
Live rats and mice as lures	Lures for traps	Use of live rodents of no benefit and added to workload	Lawrence (1999)
Prey odours as lures	Lures for traps	Ship rat odour identified as a lure;	Byrom in Murphy & Fechney (2003)
Freeze-dried versus fresh rabbit as lures for traps	Lures for traps	Equivocal results	Miller (2003)
Freeze-dried rodents versus eggs as lures for traps	Lures for traps	Eggs best	Burns in DOC (2002)
Sound lures	Lures for traps	Unclear results in pen trials	Spurr & O'Connor (1999)
Using colours to increase trap success	Lures for traps	Yellow trap covers better	Hamilton in Murphy & Fechney (2003)
Lure type	Lures for traps	Eggs best	Dilks et al. (1996)
Micro-site selection	Trap density/layout	No pattern detected at micro-site level	Lawrence in DOC (2001)
Trap position	Trap density/layout	Edge traps best	Dilks et al. (1996)
Effect of low-density trapping in takahe area	When to set in relation to stoat density	Identified home range and core use area sizes	Smith & Jamieson (2002)
Efficacy of Fenn trapping in high-density stoat areas	Trap density/layout When to set in relation to stoat density	Large-scale, low intensity trapping protected some threatened species	Dilks & Lawrence in DOC (2000)
Collation & exploration of stoat trapping data	Efficiency & efficacy	Trapped rats and stoats attract more stoats	Christie et al. (2003)

[1] Includes research on the use of lures for traps; some results from lures may be relevant to bait development.

[2] Research projects in progress are also noted.

caught on their video so a larger sample size is needed to confirm this (Spurr & Hough 1994).

Wire mesh tunnels have been trialled and are used in the Urewera stoat control operations (Beaven 1998). These have been shown to capture significantly more stoats than wooden or buried tunnels (see Burns in Murphy & Fechney 2003). However, in a trial at Lake Rotoiti, stoats were caught significantly more often in wooden tunnels than in wire mesh ones (Butler 2002). In coastal Otago, more stoats were caught in yellow-covered traps compared to the green- or black-covered traps (Hamilton 2002).

Lures

The purposes of lures associated with traps are either to increase the stoats' ability to detect the trap/tunnel or to induce stoats to enter the tunnel with its traps once they have detected them, i.e. to increase trap attractiveness. Lures may be visual, auditory, gustatory and/or olfactory. Unlike the material used in a bait, a lure in a trap does not necessarily have to be palatable. It might help focus 'bait trials' if the primary goal (trap lure or toxic bait) was specified.

Two factors determine the proportion of stoats that are not trappable. Either an animal might never detect a trap/tunnel, or it detects a trap/tunnel but it never enters it. The management solutions are to increase the density of traps for the first problem and perhaps to use lures in the second case. The contribution of these two elements to untrappable stoats may be able to be separated experimentally.

The lures used seem to depend on a combination of availability and managers' ingenuity. Hens' eggs (even the colour and whether they are cracked or whole may affect their efficacy) are the most commonly used lure, but results of trials tcomparing different lures provide only limited results from which to recommend best practice. A trial at Lake Rotoiti found that fresh hens' eggs caught significantly more stoats than plastic eggs (Butler 2002)

Analysis of trapping data from the Hurunui Mainland Island indicated that there was an increased probability of capturing a stoat in a double set (i.e. 2 traps/ tunnel), if a rat was caught in the other trap. Traps that caught a rat were approximately twice as likely to catch a stoat, as those that had not. Traps that had caught a stoat recently were also found to have more chance of capturing another stoat (Christie et al. 2003). These findings suggest that double rather than single trap sets might be more effective for stoat control, as once an animal is captured, it acts as a lure for the other trap.

Trapping layout and design

Identifying the best strategic use of traps is a more complex problem because optimal solutions will depend on the context (e.g. the species you are trying to protect, stoat densities and whether they are increasing or decreasing with more or less alternative food; Alterio et al. 1999); and/or on seasonal effects on the vulnerability of different ages and sexes of both predator and prey. It is likely to require trade-offs between these components.

There are likely to be micro-site characteristics that improve trap success, as anecdotal evidence shows that more stoats are caught in some traps than others. However, a preliminary trial could not predict trap success (measured by tunnel use) based on nine micro-site habitat measurements (DOC 2001). A study is underway to analyse stoat trap catch data from a selection of large-scale mainland trapping operations to describe conditions which maximise stoat capture rates, and also to explore whether there is a relationship between trap layout (density and pattern) and survival of individuals from a protected population (see Christie & Brown in Murphy & Fechney 2003).

The way traps are spaced along transects and the way transects are distributed throughout an operational area currently vary considerably (Brown 2003), however, a DOC best practice guide for stoat control operations is now available to DOc staff on the DOC Intranet.

Formal adaptive experimental management could provide the most efficient way to improve the use of traps. We note a similar problem with variable usage of baits to control foxes in Victoria is being studied using an adaptive management experiment (AEM) (Robley & Choquenot 2002). Generally, any AEM trial to disentangle these usage parameters would need to carefully consider whether the response variable should be a measure of efficiency, e.g. stoats caught per trap at different trap densities, or efficacy, e.g. residual stoat densities, or both; plus some measure of the benefit provided to native prey species. For example, King (1980) showed that catch per trap did not alter with trap spacings of between 100 m and 800 m, but this provided no information on whether trap spacing affected the proportion of the population killed. Similarly, there is no best practice information on the optimal frequency with which traps should be visited to remove victims or replace the lures, or on the most effective time of year to set traps (other than when their impact is likely to be most severe, such as during the breeding season).

4.2 BAITS FOR USE WITH TOXINS OR CONTRACEPTIVES

4.2.1 Current uses and advantages

A bait with a toxin, pathogen or contraceptive can be used to kill or sterilise stoats. Only toxins are currently available for use. The non-toxic bait may itself be identical with the lures used in trap tunnels. Like traps, control by baits can be divided into physical components (the bait and its active ingredients) and usage (how it is delivered, where, when and how often) (Table 3).

The advantages of poison baits over traps are that they may be cheaper for a given intensity of traps/baits, and easier to use. The risks to non-target species are probably greater than for traps, unless the poison baits are placed in bait stations that exclude non-target species that would otherwise eat a meat- or egg-based bait.

4.2.2 Constraints

All physical components of a bait can be manipulated to improve stoat control, perhaps enough to meet our ‘order of magnitude’ aim (Table 3). However, a bait has to balance properties such as bait life in storage and in the field, cost, ease

TABLE 3. COMPONENTS OF BAITS AND THE MAIN CONSTRAINTS AND RISKS.

BAIT COMPONENT	MAIN CONSTRAINTS	MAIN RISKS
Bait material	Bait life; robustness for delivery methods; palatability	Palatable to non-target animals
Bait size	Providing lethal dose in one bait that a stoat will eat	Sub-lethal dosing
Type of toxin	Detection by stoats; toxicity and efficacy	Public acceptability; non-target toxicity
Type of contraceptive	Lack of tested agent (see Sections 4.4.2 & 4.5.2)	Not species-specific
Type of biocontrol agent	Constraint: lack of tested agent (see Section 4.3.2)	Effects on non-target species and public acceptability of GMOs if used
Bait palatability	Palatable bait that is useful in the field is not available	Ingestion of sub-lethal amounts can lead to bait shyness
Bait acceptance	Few measures in the field	Uncertainty as to cause of non-acceptance
Bait delivery	Currently, all ground-laid	Non-target toxicity
Baiting frequency	Lack of data to identify best strategy	Ineffective control
When to set bait in relation to stoat density	Lack of best practice data	Systems may be unpredictable

of handling and safety, and its ability to contain enough active ingredient to produce a palatable product delivering maximum acceptance.

Currently, all bait properties, including the toxicity and efficacy of the toxicants, put some constraints on the availability of a bait with high acceptance.

4.2.3 Risks

The main risks are those associated with all baits: an unknown proportion of stoats may never eat even the best bait; there are risks to non-target species and the environment from the toxin; and there are social risks, where people are opposed to the active ingredient.

4.2.4 Ways to overcome constraints and risks

Three approaches are possible in developing a bait. The first (and that currently followed) is to focus on bait palatability as the proximal measure of success, and attempt to manipulate the ingredients (e.g. to enhance bait life) without compromising palatability (e.g. Henderson et al. 2002). The second is to focus on the behaviour of the stoats in an attempt to understand why they do or do not eat a bait in order to illuminate how a bait fails or succeeds (e.g. Clapperton et al. in Murphy & Fechney 2003). The third approach is to specify exactly how a virtual bait must perform to be of any, or optimal, use and then design a real bait by balancing the components that have to go into it, e.g. Landcare Research's approach to developing a possum immunocontraceptive bait (see Appendix 2).

All approaches share some information needs, and work in one informs the others. However, the third approach has some advantages over the others, largely because its proximal measure of success is not palatability but acceptance, i.e. it is not how much bait is eaten, but how many stoats eat the bait that ultimately counts.

Bait formulation

Current research on bait development has focused on palatability trials in the field (bait-take), and on the palatability and life of various bait formulations in pens (Murphy et al. 1992; Spurr et al. 2001; Henderson et al. 2002). Only limited measures of acceptance are possible in pen trials because of the artificial environment and small number of stoats tested (Table 4).

The trials have had no common design so that comparisons of palatability between different potential baits across trials are fraught. For example, Spurr et al. (2001) compared novel baits with the best current bait (eggs), while Henderson et al. (2002) compared 'best novel bait to date' with the 'best novel bait plus some new component'.

Lures

As with traps, stoats might be lured to baits or bait stations by some signal (visual, auditory or olfactory) to ensure the animals detect the bait. The bait itself might contain a lure (usually olfactory or gustatory) to tempt the stoat to approach the bait and eat it. It becomes a moot point if additives to increase the palatability of a bait are lures or part of the basic bait.

Toxins

Although there are currently no poisons registered for stoat control, the availability of a suitable toxicant is unlikely to constrain stoat control if a suitable bait is available, i.e. if an individual stoat can be induced to eat enough of a toxic bait. Trials have been conducted using 1080 (Spurr et al. 1998; Spurr

TABLE 4. RECENT RESEARCH ON BAITS[1] FOR STOATS ADDRESSING CONSTRAINTS/RISKS TO THEIR USE.

RESEARCH PROJECT	CONSTRAINT/RISK (SEE TABLE 3)	KEY RESULTS FROM COMPLETED RESEARCH[2]	REFERENCE
Development of long-life bait	Palatability of protein, gel and paste bait formulations; bait life	Identified best bait consistency	Henderson et al. (2002)
Bait types with and without toxin	Palatability and acceptance of 18 baits compared with eggs	No bait was as palatable or acceptable as hens' eggs	Spurr et al. (2001)
Bait trials	Palatability and acceptance	Eggs and mice better than cat food	Murphy et al. (1992)
Use of 1080 in eggs	Acceptance	Most stoats ate eggs and died	Dilks & Lawrence (2000)
Long-life toxic baits	Palatability and acceptance	All stoats ate hens' eggs injected with toxicants but would not readily eat long-life fish-meal or cereal-based baits	Spurr (1999a)
Palatability and life of a novel bait	Palatability and bait life	In progress	Clapperton in Murphy & Fechney (2003)
Zinc phosphide/1080 – micro-tablet for stoats	Palatability and acceptance	In progress	Kerr in Murphy & Fechney (2003)
Development of a marker for bait trials (Iophenoxic acid)	Technique to measure acceptance	Marker worked	Spurr (2002a)
Development of a marker for bait trials (Rhodamine B)	Technique to measure acceptance	Marker worked	Spurr (2002b)

1 Projects where the primary aim of the bait was to act as a lure for traps are listed in Table 2.

2 Research projects in progress are also noted.

1999a, 2000; Dilks & Lawrence 2000), cholecalciferol (Spurr 1999a; Spurr et al. 2001), and diphacinone (Spurr et al. 1998; Spurr 1999a; Lawrence & Dilks 2000). The results for diphacinone were equivocal and further trials would be needed.

Wickstrom & Eason (1999), Spurr (1999b) and Marks (in DOC 2001, 2002) reviewed potential toxicants for mustelids. Apart from the general toxins 1080, cholecalciferol, and anticoagulant rodenticides (which all kill stoats), several new compounds are being tested. The most promising is a toxic compound carnivores appear to be particularly susceptible to (O'Connor 2002). In trials with non-target species, however, ducks (*Anas platyrhynchos*) were also relatively susceptible, so further non-target trials are needed to determine risks to other species.

The main risks facing the use of toxins are their lack of social acceptability. Focus group surveys suggest that poisoning stoats would be tolerated rather than supported, and that poisoning was worse than trapping but better than biocontrol, especially if the agents for the latter were genetically engineered (Fitzgerald et al. 2002).

4.3 BIOLOGICAL CONTROL USING A PATHOGEN OR PARASITE TO INCREASE MORTALITY

4.3.1 Potential uses and advantages

Pathogens have been successful in the deliberate control of pest vertebrates, e.g. myxoma and rabbit haemorrhagic disease (RHD) viruses in rabbits (*Oryctolagus cuniculus*; Fenner & Fantini 1999; Parkes et al. 2002); in the natural reduction (at least over several years) of some introduced species in New Zealand, e.g. *Salmonella typhimurium* in sparrows (*Passer domesticus*), and an unknown agent in hedgehogs (J. Flux, pers comm.); and in the undesirable reduction of populations of many vertebrates, e.g. rinderpest in ungulates in Africa (Sinclair 1977), or canine distemper in black-footed ferrets (*Mustela nigripes*) in North America (Williams et al. 1988). Thus, the possibility exists that such a biocontrol agent might be found among stoats, other mustelids, or other vertebrates outside New Zealand.

Stoats in New Zealand can be infected or carry a variety of diseases and parasites, but fewer than they carry in other countries (Appendix 3). They can catch bovine tuberculosis (Ragg et al. 1995). They also carry nematodes (*Skrjabingylus nasicola*; King & Moody 1982), fleas (mostly a rat flea, *Nosopsyllus fasciatus*; King 1990), mites (including *Demodex erminea*; Tenquist & Charleston 2001), and the louse (*Trichodectes erminea*; King 1990). Canine distemper is present among dogs in New Zealand and stoats are known to be susceptible to the virus (Keymer & Epps 1969). Some of the earlier vaccine strains of canine distemper developed for dogs caused mortality in ferrets. This has led to the possibility, currently being investigated, of using a vaccine strain of canine distemper virus to control stoats (Zheng in Murphy & Fechney 2003). The idea of using a vaccine strain is so that dogs (and other potential non-targets) would not be susceptible, which is likely to be much more acceptable to the public—assuming it is also humane.

It is possible that a pathogen could be genetically modified to increase mortality but public acceptability of this strategy is likely to be low, even if one could be found. It would probably be more acceptable if the genetically modified pathogen was not transmissible and could only be bait delivered—that is, its release and persistence could be controlled.

4.3.2 Constraints

Several factors mitigate against any classical biocontrol being effective. First, neither the New Zealand agents nor ones from abroad appear to have much effect on stoat mortality rates. However, the causes of mortality (which is sometimes high) in stoats have never been ascertained in New Zealand, and the assumption that they are food-related or due to some density-dependent social effect, and not disease-related, remains untested. Second, some diseases that might be effective are non-specific; some strains of canine distemper kill dogs, and others are also lethal human diseases that New Zealand would go to extreme lengths to keep out of the country. Third, transmission rates in stoats may be low as it is generally assumed that the contact rates are low among 'anti-social' stoats (but sequential den use has been reported and this could aid in transmission; see Dowding & Elliott 2003). However, an agent with low mortality rates but high transmission rates would be ideal as a vector for a genetically-engineered immunocontraceptive.

4.3.3 Risks

Disease risks to other wild mustelids in New Zealand would not be a problem as both feral ferrets and weasels are also considered pests (Clapperton 2001; King et al. 2001). Domestic ferrets and mustelids, such as otters held in zoos, would need to be vaccinated or otherwise protected. However, we doubt if any novel disease would be acceptable to the New Zealand public and the 'RHD solution' of an illegal introduction would seem unlikely.

4.3.4 Ways to overcome constraints and risks

The potential for classical biological control using a natural parasite or pathogen to increase the mortality rate of stoats has been reviewed in a survey of diseases and pathogens present in stoats (McDonald et al. 2001, 2002; McDonald & Lariviere 2001). The three diseases they identified as possible agents (Aleutian mink virus, mink enteric virus and canine distemper), were also identified as posing serious non-target risks.

The DOC-managed Stoat Research Programme has commissioned research to explore the possibility of using viruses, bacteria, or parasites either as biocontrol agents or as vectors for immunocontraception (Table 5).

TABLE 5. RECENT RESEARCH ON STOAT PATHOGENS AND PARASITES ADDRESSING CONSTRAINTS OR RISKS.

RESEARCH PROJECT	CONSTRAINT/RISK	KEY RESULTS FROM COMPLETED RESEARCH[1]	REFERENCE
Helicobacter sp. in stoats	Potential parasite or vector	Confirmed presence in NZ stoats	Forester et al. (2003)[2]
Modelling stoat dynamics	Proportion that need to be exposed	Model only	Barlow & Choquenot (2002)
Using a vaccine strain of canine distemper to control stoats	Survey of status Virulence of vaccine strains being tested	In progress	Zheng in Murphy & Fechney (2003)
Diseases and pathogens of stoats	Survey of knowledge	Summarised what was known	McDonald & Lariviere (2001)
Disease and pathogens of stoats in Great Britain	No previous screening of British wild stoats	Screened for diseases, *Bartonella* possible candidate	McDonald et al. (2001)
Disease and pathogens of stoats and other wildlife in NZ	No previous widespread screening in NZ	Screened for diseases, *Bartonella* possible candidate	McDonald et al. (2002)
Screening of viral disease in stoats from NZ	No previous widespread screening	In progress	McDonald et al. in Murphy & Fechney (2003)
Protocols to survey for pathogens	Techniques	Provides some guidelines on sampling	O'Keefe (2001)

1 Research projects in progress are also noted.

2 Funded by Landcare Research.

4.4 DISRUPTING REPRODUCTION BY IMMUNOCONTRACEPTION

Stoats have an unusual breeding system that lends itself to disruption at various stages. Females of the year can be mated and conceive before they leave the nest while still blind and only 3 weeks old. After conception in the spring (for both adults and the young of the year), the embryos develop for about 2 weeks to the blastocyst stage and then development is arrested. The blastocysts float free in the uterus for about 9 months (diapause), implant the following spring and then the embryos develop to full term in about 4 weeks. Females rear the young alone and the young are weaned at 6–8 weeks old. Stoats can only produce one litter a year, so if reproduction can be disrupted they cannot have another litter until the following year.

Stoats do not have pair bonds and the males are promiscuous, covering large distances looking for receptive females. Hence, trying to disrupt male fertility is unlikely to be as successful a strategy as disrupting it in females.

All else being equal, disrupting diapause appears to be the best option for interfering with stoat breeding, as it offers a long window of opportunity (see Table 6).

4.4.1 Potential uses and advantages

Immunocontraception, which can disrupt reproduction at any point from fertilisation to birth, is being developed for possums in New Zealand (Cowan 2000), and for mice (*Mus musculus*), foxes (*Vulpes vulpes*) and rabbits

TABLE 6. POSSIBLE STAGES IN STOAT REPRODUCTION THAT MIGHT BE TARGETED FOR DISRUPTION.

REPRODUCTIVE STAGE	CONSTRAINTS	RISK
Stop fertilisation occurring	Juvenile females can mate when 3 weeks old and still in the den	May not deliver to females before they are fertilised
Disrupt embryonic diapause (8–9 month window of opportunity)	Finding the right target antigen or chemical	May not be deliverable to enough females to cause population decline
Disrupt implantation e.g. maternal expression of leukaemia inhibitory factor	Window of opportunity is small	May not be deliverable to enough females in short target period
Cause abortion after implantation	Window of 4 weeks but females are wary at this time of year	May not be deliverable to enough females in the time available
Stop lactation	Finding the right target antigen or chemical	May not be ethically acceptable
Interfere with male fertility	Promiscuous lifestyle; no pair bonds	May not be deliverable to enough males

(*Oryctolagus cuniculus*) in Australia (Tyndale-Biscoe 1994; Seamark 2001). The potential of the method as a stoat control tool in New Zealand has been reviewed by Hinds et al. (2000). An immunocontraceptive needs some target protein in the stoat's reproductive system that can be disrupted by a bait or living vector genetically engineered to express the contraceptive antigens. The prerequisites for this system are summarised in Table 7.

The potential advantage of the technique is the same as for a classical biocontrol mortality agent, providing a self-replicating vector can be found. That is, a long-term benefit for the single cost of releasing a successful agent. However, unlike a mortality agent, the range of potential vectors may be wider as the agent can be an attenuated strain of a pathogen or a completely benign agent. Modelling by Barlow (DOC 2001) has indicated that, in the long term, culling and fertility control of stoats are equally effective, with fertility control being more effective in beech than in non-beech forests. This makes stoats a potentially good target for vectored immunocontraception. If no self-replicating vector is found, a bait-delivered approach is still possible and is a likely first step for proof of performance.

4.4.2 Constraints

The main constraint on the technique is that it has not yet been taken past the 'proof of concept' phase for any other vertebrate pest (Cowan 2000; Hinds et al. 2000). It is also possible that non-response to an antigen could be inheritable. Therefore, given the short generation time of stoats, multiple antigens would be of benefit. If a disseminating vector was used for delivery, the solitary lifestyle of stoats could mean transmission rates may be too low to sustain the agent without ongoing releases. A venereal agent would overcome this problem. If a non-disseminating agent was used, the main constraint is the lack of an effective bait (see Section 4.2.2).

TABLE 7. PREREQUISITES FOR A SUCCESSFUL STOAT IMMUNOCONTRACEPTIVE. (THE ACTIVE AGENTS/VECTORS MIGHT CAUSE CONTRACEPTION OR DEATH DEPENDING ON THE AGENT/SYSTEM TARGETED.)

COMPONENT OF IMMUNOCONTRACEPTION	MAIN CONSTRAINTS/RISKS	HOW TO SOLVE THEM
Identification of target antigen	Constraint: technical Risk: species specificity	Identify more than one target antigen Choice of target Epitope mapping to find specific sequences of proteins
Efficacy (% of stoats reacting; length of sterility)	Constraint: technical Risk: inheritable non-response	Pen and field trials Modelling Integrated pest management
Mechanism to deliver the the active agent (general)	Constraints: lack of identified vector; possible low transmission rates Risk: NZ and international public acceptability	Search for a candidate vector Observe public reactions
Agent delivery option 1: Non-disseminating GMOs, e.g. bacterial ghosts, transgenic plants, or virus-like particles	Constraint: lack of a bait in which to put the potential agent Risk: public opposition	Research on baits and antigen production
Agent delivery option 2: Live viruses or replication-limited viruses	Constraints: lack of a candidate virus; low transmission rates Risk: public opposition	Vaccine strain canine distemper virus possible Model transmission rates
Agent delivery option 3: Bacteria	Constraint: agents generally not host-specific Risk: public opposition	Investigate host-specificities and possible gene transfers
Agent delivery option 4: Multicellular parasites	Constraints: unknown prevalences and host-specificity Risk: public opposition	Investigate prevalences, specificity and transmission rates
Bait delivery	Constraint: lack of bait (see Section 4.2.2.)	Develop a bait

4.4.3 Risks

There are two main risks. First, the research necessary to take the method past some initial proof of concept (i.e. identification of an antigen and some preliminary trials on the response rates of stoats exposed to it) is currently unfunded. The preliminary trials (Table 8) should be completed by 2004, but the more difficult phases of developing delivery mechanisms will take several more years of research. Options to fund this work need to be explored now to justify current expenditure.

Second, public acceptability of genetically modified agents is a major risk that might halt this technique even if it proves technically feasible. The fate of the current work on mice in Australia, and possums in New Zealand, will send early signals on the value of proceeding with research on stoat immunocontraception.

TABLE 8. RESEARCH IN PROGRESS ADDRESSING RISKS/CONSTRAINTS TO IMMUNOCONTRACEPTION.

RESEARCH PROJECT	CONSTRAINT/RISK	KEY RESULTS FROM COMPLETED RESEARCH	REFERENCE
Stoat reproductive biology	Basic understanding of reproductive cycle	In progress	O' Connor et al. in Murphy & Fechney (2003)
Artificial stoat reproductive biology	Basic understanding in vitro	In progress	La Falci & Molinia in Murphy & Fechney (2003)
Monitoring hormones	Basic methodology	In progress	La Falci & Molinia in Murphy & Fechney (2003)
Zona pellucida antigens	Finding a target for immune response	In progress	Duckworth et al. in Murphy & Fechney (2003)

4.4.4 Ways to overcome constraints and risks

Many of the constraints can only be tested by proceeding with attempts to identify and test potential antigens. It is possible that the system of delayed implantation in stoats will give a high response rate to the contraceptive agent, especially as the phase lasts for 8–9 months which gives each female stoat many chances of encountering the vector or bait.

Initial research has focused on elucidating some basic reproductive physiology and development of the techniques required to measure reproductive responses; also, on one component of the system—the zona pellucida antigens—that might be a suitable target (Table 8).

4.4.5 International obligations

Although stoats are a major conservation problem in New Zealand, they are an integral and valued part of the native fauna of North America and Europe. A specification for any stoat biocontrol product must be that it meets international obligations. This is not such a problem for non-disseminating systems but if a transmissible vector were being considered as a delivery mechanism for reproductive (or lethal) control, then international consultation should begin in the early stages to determine how likely it would ever be acceptable. Unfortunately, it is not entirely clear whom to consult internationally. New Zealand is a signatory to the Convention on Biological Diversity, and Article 14 (c) of the Convention text states that each Contracting Party shall promote notification, exchange of information and consultation on activities under their jurisdiction or control which are likely to significantly adversely affect the biological diversity of other States or areas beyond the limits of national jurisdiction. A supplementary agreement to the Convention, the Cartagena Protocol on Biosafety, came into force in September 2003 (although New Zealand has not yet ratified it). This protocol seeks to protect biological diversity from the potential risks resulting from transboundary/ international movements of GMOs. However, this protocol deals mainly with intentional movements, rather than with unintentional ones. Other international agreements are likely to be applicable, e.g. the World Trade

Organisation Agreement on the Application of Sanitary and Phytosanitary Measures (WTO/SPS). The WTO/SPS recognises two international technical organisations that could provide guidance—the International Plant Protection Convention (IPPC) and the Office International des Epizooties (OIE). However, none of these deal with assessing risks in the development phase, and the application of these agreements to transmissible forms of genetically modified animal-control agents is unlikely to have been tested.

Observation of the national and international reactions to the proposed use of GMOs as immunocontraceptives for mice in Australia and possums in New Zealand over the next few years will set some of the stop or go rules for investment in such research on stoats.

4.5 DISRUPTING REPRODUCTION USING CHEMICALS

Reversible contraception techniques have been developed in companion, zoo and indigenous animals, but these techniques would be of little use to stoat control. Delivery is generally by targeting individual animals through repeated capture and/or treatment and current international research is focusing on development of single-shot vaccines (Turner et al. 2002).

4.5.1 Potential uses and advantages

Delivering a chemical contraceptive to a wild animal, such as the stoat, that cannot be captured is likely to require a bait. One technique being investigated for mule deer (Nett et al. 2001) and possums (Eckery et al. 1999) is the conjugation of a plant cytotoxin to a gonadotrophin-releasing hormone (GnRH) agonist. This targets a toxin to Lutenising Hormone- and Follicle Stimulating Hormone-secreting cells in the anterior pituitary, to prevent gamete production by the ovaries and testes. GnRH is highly conserved across species, so a single GnRH-toxin conjugate has the potential to affect reproduction in both sexes of numerous species. Therefore, species-specific delivery mechanisms will need to be developed. GnRH receptors are also located in other areas, e.g. the kidney, in some species (L. Miller, The National Wildlife Research Centre, Fort Collins, USA, pers. comm.), which would render any GnRH-toxin conjugate inappropriate for reproductive control.

Ingestion of dopamine agonists, e.g. cabergoline and bromocriptine, results in prolonged, lowered prolactin levels, causing abortion and inhibiting lactation in a number of animals (Hinds et al. 2000; Norbury 2000). These compounds can be delivered orally in baits but ingestion of baits by non-target species could be a problem. Female stoats are known to be harder to catch in the later stages of pregnancy and when lactating (King & Moody 1982), and may also be more wary of eating baits during that time.

Orally delivered dopamine antagonists are likely to disrupt diapause, as they elevate prolactin levels (Murphy 1983; Marks in DOC 2002). Elevation of prolactin levels, could cause precocious implantation of the blastocycts leading to either death of the blastocysts or out-of-season births (Murphy 1983).

Summaries of the advantages and disadvantages of some chemosterilants that may reduce fertility in stoats are given in Hinds et al. (2000) and Norbury (2000).

4.5.2 Constraints

The main constraint is the lack of an efficient delivery mechanism, a bait. As with toxins and oral immunocontraceptives, too few stoats are likely to eat current baits to have any significant effect on the stoat population. Alternatively, a high proportion of stoats might be affected and become sterile, but the affected population might still be too large and cause unacceptable impacts. The cost and availability of the compounds may also constrain their use.

4.5.3 Risks

Most chemical agents are not specific to stoats; and inhibiting lactation (and the consequent starvation of young animals) with dopamine agonists may not be ethically acceptable.

4.5.4 Ways to overcome constraints and risks

The proportion of females that would have to be sterilised to affect stoat population size has been modelled (Barlow & Choquenot 2002), so the efficacy of a sterilant and bait could be assessed in trials. The non-specific problems might be overcome by delivering the baits. The delivery of dopamine antagonists would present the lowest risk, as baits could be delivered during autumn when stoats are pregnant but most other native vertebrate species are not.

4.6 SECONDARY POISONING

4.6.1 Current uses and advantages

Large-scale poison operations (both aerial and ground) are routinely used to control possums and ship rats (*Rattus rattus*) in New Zealand. The two main toxins used have been 1080 and brodifacoum. These operations also inadvertently kill stoats, ferrets and cats (*Felis catus*), through secondary poisoning when the animals eat poisoned rat and possum carcasses (Brown et al. 1998; Gillies & Pierce 1999; Murphy et al. 1999; Alterio 2000). Diphacinone also kills stoats through secondary poisoning (Spurr & O'Connor 1998).

Stoats may also be killed by eating live prey that have consumed persistent poisons such as anticoagulants, i.e. live prey containing either sub-lethal doses of toxin containing lethal doses but before they die.

4.6.2 Constraints

The toxins currently used in New Zealand are only registered for the target pests, generally possums, so the deliberate use of them to target stoats is illegal. Although a high percentage of stoats may be killed initially by secondary poisoning, the effect is likely to be short-lived because control aimed at the primary pest is often too infrequent to provide anything but short-term control of stoats given their ability to reinvade treated areas (Gillies & Pierce 1999; Murphy et al. 1999).

4.6.3 Risks

DOC aims to minimise persistent toxins in the ecosystem, and so will not, as a matter of course, aim to kill stoats via sub-lethally poisoned prey. However, stoats killed as bycatch from eating dead prey are a bonus from possum/rat control operations, especially those using non-persistent toxins such as 1080.

Misuse of toxins might compromise their legitimate use against primary pest species, so any deliberate use against stoats should be registered. Such registration would then need to take account of the risks posed, particularly by persistent toxins, to human health and non-target native and exotic species. For example, brodifacoum residues have been found in kiwi and morepork (*Ninox novaeseelandiae*); in deer (*Cervus* spp.); and in feral pigs (*Sus scrofa*) (Murphy et al. 1998; Robertson et al. 1999; Eason & Murphy 2001). Their presence (even at sub-lethal doses) in native species is undesirable, and their presence in deer and pigs has contributed to restrictions (since 2002) on the commercial harvest of these species and a threat to halt the trade (Parkes in press). A ban on commercial hunting would have a substantial negative effect on conservation values, particularly in alpine grassland ecosystems that are kept largely deer-free by commercial hunters (Nugent et al. 2001).

4.6.4 Ways to overcome constraints and risks

It is unlikely that persistent toxins will be registered for use as a stoat control tool via sub-lethally poisoned primary prey. However, registration of acute poisons such as 1080, or of a less-persistent toxin to target both rodents and stoats might be considered. The Department should await the outcome of the current review of 1080 under the Hazardous Substances and New Organisms Act before considering the costs and benefits of this action.

4.7 CONTROL OF PRIMARY PREY

4.7.1 Potential uses and advantages

The abundance of stoats may be limited and/or regulated by the abundance of primary prey such as rodents. Mice are a major prey item of stoats in beech forests and there is a significant correlation between stoat and mouse abundance (King 1983). Rodents are themselves pests and so control of rodents might be one way to limit the number, and perhaps the impact, of stoats.

4.7.2 Constraints

The main problem with controlling primary prey is that sustained control of rodents (at least in areas where eradication is impossible) is at least as difficult as controlling stoats. Also, in North Island forests, where ship rats are a major prey of stoats, the relationship between stoat and rat abundance is not so clear. In one study, a significant inverse correlation between stoat and rat tracking rates was found (Murphy et al. 1999). In another study, catch rates of stoats did not decline with a dramatic decline in rat abundance (Murphy & Bradfield 1992).

4.7.3 Risks

Controlling primary prey can cause stoats to alter their diet to consume more secondary prey (often native species) and so, at least in the short term, cause more harm than good. In two North Island podocarp forests, birds were eaten more frequently by stoats when rats were scarce (Murphy et al. 1998).

4.7.4 Ways to overcome constraints and risks

Research (informed by modelling) to understand the interactions between primary prey, stoats and secondary prey, and on how to control rodents, might indicate if manipulation of primary prey could be effective.

Control of mice as a primary prey of stoats might be achieved in New Zealand if the current research on mouse immunocontraceptives by the Pest Animal Control Control Research Centre in Australia proves successful (Seamark 2001), and if the agent (a genetically modified virus) is released in New Zealand.

4.8 USE OF DOGS

4.8.1 Current uses and advantages

The Department has a ‘predator dog project’ to assess the use of trained dogs to track and find stoats and other predators. To date the work has concentrated on detecting stoats remaining in areas subjected to conventional trapping (Trounson and Boundary Stream mainland islands, Mimiwhangata, Bream Head, and the Burwood takahe area); on islands in Fiordland where an attempt is being made to remove stoats; and on stoat-free islands where there have been unconfirmed reports of stoats (Stewart and Great Barrier islands)—fortunately, without success on Stewart and Great Barrier Islands (E. Murphy, unpubl. data).

Magtoxin (magnesium phosphide pellets that release the toxic gas phosphine in contact with water) has been used to kill stoats in their dens when they are identified by tracking dogs. In one trial 15 den sites were found and treated, resulting in 20 stoats being removed from three occupied dens (Theobald & Coad 2002).

The advantages of the method are obvious for these specialist situations. Whether the method would be cost-effective as a primary stoat-control tool is under investigation. (Murphy & Fechney 2003)

4.8.2 Constraints

The main cause of den control failure to-date has been that not all the den entrances could be located and blocked, and Magtoxin is only effective in a sealed area.

Currently, the lack of trained dogs and handlers would limit this method even in its specialist role at detecting remnant or establishing animals.

4.8.3 Risks

There seem to be few risks associated with the method, providing it is used properly, although we have seen no information on the humaneness of Magtoxin use.

4.8.4 Ways to overcome constraints and risks

An increase in the number of dogs and handlers should be made as appropriate needs are identified. Other possible den control methods such as carbon monoxide fumigation should be investigated. Carbon monoxide is also likely to be more humane than magtoxin.

4.9 FENCING

4.9.1 Current uses and advantages

Fencing to exclude stoats is almost always part of fencing to exclude all or most mammals from the highly specialised mainland island reserves such as Karori (Campbell-Hunt 2002) and Karapiro (Day & MacGibbon 2001), or from small nesting areas and large aviaries where any risk from stoats is unacceptable. The advantages of fencing are strategic—the permanent removal of threat for the single (large) cost of erecting the fence plus the sustained costs of maintenance, monitoring, and efficient action against breaches. Fencing is the only way to ensure even the short-term absence of stoats at mainland sites.

Clapperton & Day (2001) modelled the relative costs of fencing versus conventional control for operations of different areas. They concluded that fencing was a cheaper alternative than conventional control over time. However, two of their assumptions may not have been valid. First, they assumed the costs of eradicating stoats from an area would be equal in both cases. Eradication would be a necessary condition of a fencing project but is never expected or attempted in a sustained control strategy, and the costs of removing the residual population of a pest may exceed (sometimes by far) the costs of achieving an acceptable target density in a sustained control operation. Second, although they assumed ongoing maintenance costs for the fence, they assumed no breaches and subsequent costs to monitor for them and deal with failures.

4.9.2 Constraints

Finding suitable areas where stoats can be eradicated and fences erected and defended against the ravages of nature, catastrophe, and human perversity, constrain sites where fences are worth considering.

For example, Clapperton & Day (2001) recommend peninsulas as suitable sites, although techiques to stop stoats swimming around the barriers remain to be developed.

4.9.3 Risks

The risks of strategic fencing mainly come from an inability to detect and deal with the inevitable breaches. The frequency of breaches is currently unknown, and difficult to detect with current methods (e.g. Choquenot et al. 2001) making a cost-effective reaction difficult to plan.

4.9.4 Ways to overcome constraints and risks

Experience with current and planned fences will allow better estimation of the rate of breaches and the costs to detect them (see Choquenot et al. 2001) and deal with the culprits. This should inform managers where it is worth attempting fencing.

4.10 REPELLENTS

4.10.1 Potential uses and advantages

Acoustic or chemical repellents have been mooted as possible ways of deterring stoats from eating prey. Spurr (1997) tested two ultrasonic devices to see if they could deter stoats, but found they had no effect in pen trials. Chemical repellents have not been tested against stoats.

4.10.2 Constraints

Even if a repellent could be found that worked, it would be limited to static defence around areas like the nest sites of potential prey. Conditioning predators to avoid prey has been mooted as a way of generalising avoidance responses, but trials to date (on ferrets) have proved disappointing (Grant Norbury, Landcare Research, pers. comm.).

4.10.3 Risks

The main risk of investment in this area is that the repellents will not work.

4.10.4 Ways to overcome constraints and risks

Considerable research would need to be conducted to make these approaches useful.

5. Conclusions

The following conclusions and recommendations are ordered according to our assessment of the likely benefits and risks of failure of each major control method for stoats.

5.1 BAIT DEVELOPMENT

The lack of choices available to managers for an effective bait for use with toxicants or contraceptives is the main constraint on a variety of current and potential control methods for stoats. We see success in this area as being the most likely to deliver improved stoat control, perhaps of the magnitude we set in the introduction to this review, in the medium term.

A variety of bait types are needed for different delivery routes (aerial, ground-laid or via bait stations); and they need to contain different active ingredients (toxins, sterilants, living or dead biocontrols). The approach recommended in developing new baits is to specify a range to be met for each bait characteristic (size, robustness, bait-life and palatability) for its particular mode of delivery (aerial, ground, bait-station and which active ingredient). These characters can then be manipulated within their desired range to maximise bait acceptance in the field.

5.2 TRAPPING

In the short-term, trapping is likely to continue to be the main control method. New kill traps need to be developed that are humane and efficient, and the best ways of setting them with tunnels and lures need to be investigated by pen and field experiments. It might be productive to separate the search for better lures from the research on bait development for toxins and sterilants.

More generally, there are likely to be significant gains in stoat control effectiveness in the strategic usage of traps. Improved record-keeping will allow better progress to be made.

5.3 FERTILITY CONTROL

Disruption of stoats' reproduction to limit their numbers has a range of potential benefits. These range from modest, if the agents all have to be delivered in a bait, to very high, if they act as a self-replicating biocontrol. None of the current options has been taken past the 'proof of concept' phase for any wild animal pest, but preliminary research on stoats has been justified by DOC because it can build on the work already underway in Australia and New Zealand on mice and possums.

However, the work remains risky and a cautious approach is recommended, with clear 'stop-rules' should either the mouse or possum programmes fail. For example, public disapproval over GMO usage may make further research unwarranted, there may be a lack of commitment by funding agencies to invest in long-term stoat research, or there may be a lack of success in other research, such as the development of a bait to deliver a fertility control agent, upon which fertility control is dependent.

5.4 CLASSICAL BIOLOGICAL CONTROL

Biological control using a pathogen or parasite has the potential to achieve widespread stoat control but unfortunately no species-specific candidate has been identified. We recommend completion of trials on the vaccine strain of canine distemper but no further targeted work in this area unless some unexpected result appears that suggests higher chances of success.

One key issue that both fertility control and classical biological control need to address is the lack of data on contact rates of stoats.

5.5 MINOR CONTROL METHODS

None of the other methods (secondary poisoning, dogs or fences) are likely to deliver sustained, widespread control of stoats, but several boutique methods (use of dogs and fencing) might prove useful adjuncts to the stoat control armoury.

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Appendix 1

GLOSSARY OF TERMS USED IN THIS REPORT

Acceptance: the proportion of a stoat population that will eat a bait. This measures two distinct parameters; the proportion of stoats that detect and approach a bait (partly measuring attractiveness) and the proportion that subsequently eat it.

Adaptive experimental management (AEM): can mean several things, all of which involve using normal management practices as though they are a treatment in an experiment whose outcome is then measured. At its simplest, adaptive management can be a step-wise approach where some management is tried, the result measured, changed in some way, tried again and remeasured to see if the change improved the result. However, over the last decade this idea has been extended to include the concepts of experimental design. The differences in management are the treatments in an experiment that are interrogated via formal hypothesis testing with a model to predict outcomes and the niceties of replication, randomisation and experimental controls (see Parkes & Choquenot 1999).

One key to success of an AEM project is having a clear question to answer that cannot be addressed in an ordinary experiment. For stoats, the obvious area for an AEM experiment is to optimise the strategic use of traps and baits, which are by their nature large-scale, complex, and have a temporal component. For example, what is the best density of traps, and when should they be set in relation to the density of stoats, primary prey, or impacts on particular native species. Tactical questions (e.g. is this trap better than that one?) are best answered with ordinary experiments—being conducted by managers or scientists does not make these adaptive management experiments.

Attractiveness: the proportion of a stoat population that detects and approaches a lure or bait.

Bait: something a stoat must eat, cf. a lure in a trap which does not have to be eaten.

Lure: any cue (visual, auditory, scent, or food) used to attract stoats to a trap or bait. The lure may be contained in, or separate from, the bait.

Palatability: the amount of bait eaten by a stoat, often used relative to another bait.

Strategy: where, when, how often, and how intensively to apply control tactics.

Tactics: the range of control methods available to use.

Zona pellucida: an extracellular coat around mammalian eggs which plays an essential role during fertilisation and early development of the embryo.

Appendix 2

BAIT DESIGN

Ideal baits for stoats must be cheap, safe, available on demand, storable, and suitable for distribution by a variety of means, e.g. from the air, on the ground by hand, or in bait stations. They must be palatable, able to include toxicants or other active ingredients, of the right size so a stoat can eat all or at least enough to get a lethal dose—all resulting in high acceptance (Table A2.1). Factors that might enhance acceptance include attractiveness, palatability, bait-life, and bait layout and density.

A bait used to lure stoats to a trap need only be attractive and have optimal bait-life characteristics, palatability is not required.

The methods of measuring acceptance have been well established for possums (Morgan 1982) and rabbits (Bell & Ross 1982), and essentially involve presenting wild populations with non-toxic baits marked with a dye (rhodamine B is commonly used; Fisher 1999; Spurr 2002b) or blood marker (iophenoxic acid is commonly used; Eason & Batcheler 1991; Forsyth & Parkes 1995; Spurr 2002a), and later capturing a sample of animals and recording what proportion are tagged with the marker. The question remains whether non-acceptance is due to the stoat not encountering a bait, or encountering it but not eating it (the measure usually claimed as acceptance in pen trials when presumably all stoats encounter a bait).

TABLE A2.1 EXAMPLES OF BAIT DESIGN PARAMETERS THAT MIGHT BE USED IN DIFFERENT DELIVERY METHODS.

BAIT PARAMETER	GROUND	BAIT STATION	AERIAL
Bait weight	3–5 g	More flexible than ground or aerial?	3–5 g
Bait robustness	Flexible	Could be fragile	Tough
Bait life	Variable	Long (c. 160 days)	Variable –short
Palatability at least as good as eggs	Rabbit > bait > egg	Rabbit > bait > egg	Rabbit > bait > egg
Optimum acceptance	100%	100%	100%

Appendix 3

VIRUSES, BACTERIA AND PARASITES

VIRUSES, BACTERIA AND PARASITES FOUND IN STOATS IN NZ AND ABROAD, OR IN NZ MUSTELIDS (AFTER KING ET AL. 2001; MCDONALD & LARIVIERE 2001; TENQUIST & CHARLESTON 2001).

AGENT	PRESENT IN NZ STOATS	PREVALENCE IN NZ STOATS	PRESENT IN NZ MUSTELIDS	PRESENT IN STOATS ABROAD	NOTES
Viruses					
Canine distemper	?	?	?	Yes	Infects dogs
Aleutian mink parvovirus	No	0%	No	Yes	
Rabies	No		No	Yes	Infects humans
Bacteria					
Bovine Tb	Yes	1.6%	Yes	Yes	Infects cattle
Johne's disease				Yes	Infects cattle
Tularaemia	No	0%	No	Yes	Infects humans
Bartonella	Yes		No	Yes	
Borrelia burgdorferi				Yes	Infects humans
Helicobacter mustelae	Yes		Yes		
Nematodes					
Skrjabingylus nasicola	Yes	10%		Yes	
Strongyloides martis				Yes	
Filaroides martis	Yes		Yes		
Molineus patens				Yes	
Molineus mustelae					
Capillaria putorii				Yes	
Dracunculus sp.				Yes	
Aelurostrongylus pridhami				Yes	
Alaria mustelae				Yes	
Trichinella spirilis				Yes	
Trematodes					
Troglotrema acutum				Yes	
Cestodes					
Taenia mustelae				Yes	
Taenia tenuicolis				Yes	
Mesocestoides lineatus				Yes	
Acanthocephala spp.				Yes	
Mustelid-specific ectoparasites					
Trichodectes ermineae (louse)	Yes			Yes	Stoat-specific
Nearctopsylla brooksii (flea)	No			Yes	
Demodex erminae (mite)	Yes				Stoat-specific
Leporacarus mustelae (mite)	Yes				Stoat- and ferret-specific
Non-specific ectoparasites in NZ (+ many abroad)					
Nosopsyllus fasciatus (flea)	Yes				Infects rats
Leptopsylla segnis (flea)	Yes				Infects mice
Ceratophyllus gallinae (flea)	Yes				Infects domestic fowl (and other birds?)
Parapsyllus nestoris (flea)	Yes				
Gymnolaelaps annectans (mite)	Yes				Infects kiore
Hypoaspis nidicorva (bird mite)	Yes				Not usually parasitic on stoats
Eulaelaps stabularis (bird nest mite)	Yes				
Haemaphysalis longicornis (tick)	Yes				Infects most mammals

? Uncertain.