Development of Re-Setting Toxin Delivery Devices and Long-Life Lures for Rats

Elaine Murphy
Department of Ecology, Lincoln University, and Department of Conservation, Christchurch, New Zealand
Tim Sjoberg
Department of Conservation, Christchurch, New Zealand
Arijana Barun
Department of Ecology, Lincoln University, Lincoln, New Zealand
Paul Aylett and **Duncan MacMorran**
Connovation Ltd, Manukau, Auckland, New Zealand
Charles Eason
Department of Ecology, Lincoln University, and Cawthron Institute, Nelson, New Zealand

ABSTRACT: Introduced rats continue to have a major impact on biodiversity around the world, and improved control techniques are required to avoid further extinctions. We are trialing re-setting toxin-delivery systems (Spitfires) targeting a range of predators, including rats. The rat Spitfire works by firing 800 mg of a toxic paste onto the belly of the rat as it passes through a tunnel; the device then resets. When the rats groom the paste from their fur, they ingest the toxin. Each Spitfire is capable of approximately 100 doses and is fitted with a counter and a delay mechanism. We trialed 0.55% 1080 paste in the Spitfire and 15 of 15 wild Norway rats and 14 of 15 black rats died. Further trials are planned with a range of toxins to allow flexibility of use. Resetting devices that are expected to work for long periods without being serviced also require long-life lures. Preliminary trials showed urine and scats from female Norway rats were attractive to both male and female Norway rats. The volatile components from these and further trials will be identified to aid in developing a long-life lure. The long-term, effective control of introduced rats will require a range of toxins with different modes of action, a number of different delivery systems, and long-life lures.

KEY WORDS: 1080, black rat, Norway rat, *Rattus norvegicus*, *Rattus rattus*, resetting toxin device, rodenticides, sodium fluoroacetate, Spitfire

Proc. 26th Vertebr. Pest Conf. (R. M. Timm and J. M. O'Brien, Eds.)
Published at Univ. of Calif., Davis. 2014. Pp. 396-399.

INTRODUCTION

Introduced mammalian predators have been responsible for many extinctions and declines in New Zealand's native fauna. Rats (*Rattus* spp.) continue to have a major impact both in New Zealand and around the world, and improved rodent control techniques are required to prevent further declines and extinctions.

In New Zealand, rats can be controlled to very low levels on the mainland using bait stations containing a variety of poisons, kill traps, and large-scale aerial operations using sodium fluoroacetate (Compound 1080) (Innes 2005a,b, Parkes and Murphy 2003). Bait stations and traps are very labour intensive however, and rat populations can recover within months when control ceases. As a result, there has been a push to develop both resetting traps and resetting toxin delivery devices that require less-frequent servicing.

In the 1990s and 2000s in New Zealand, research was undertaken on a resetting device (the Scentinel®) that delivered a palatable liquid bait to small mammal pests (McDonald et al. 1999, King et al. 2007, King et al. 2009). The prototype was designed to dispense 100 lethal doses of poison, and was expected to last more than 5 years in the field without attention. The device however, was never commercialised. Building on the Scentinel®, a resettable toxin delivery device (the Spitfire) is being developed by Connovation Ltd (Auckland, New Zealand), Lincoln University, and the New Zealand Department of Conservation (Hix et al. 2009, Blackie et al. 2012). The Spitfire sprays toxin on to the belly of an animal when it passes through a tunnel, and the toxin is then licked off during grooming, leading to ingestion of a lethal dose. Each Spitfire is capable of delivering approximately 100 doses and is fitted with a counter and a delay mechanism. Different versions of the Spitfire are being developed to target different pest species; all use the same basic firing mechanism but have different housings and may deliver different toxins.

The long-term, effective control of rats by resetting devices will require a range of toxins with different modes of action, and will rely in part on the development of attractive, long-life lures. We are therefore investigating a range of pheromonal lures. Rat urine can signal to another rat what species it is, its sex, and reproductive status (Zhang et al. 2008, Osada et al. 2009). We will test whether urine and scats from rats are attractive to other rats (both male and female) and also how another rat species reacts to them.

This paper records the results of cage trials for rats using 1080 in the Spitfire. 1080 was developed in the 1940s in the U.S. as a rodenticide and mammalian predacide but is now principally used for the control of pests in New Zealand and Australia (Eason et al. 2011). The paper also reports on preliminary results of lure trials testing the attractiveness of urine and scats to Norway rats.

METHODS

Toxin Trials

Wild Norway (*R. norvegicus*) and black rats (*R. rattus*) were housed at the Lincoln University animal facility and trialled individually in a 2.4 × 0.6 × 0.8-m test cage. The Spitfire was placed inside an empty wooden DOC 200 trap box with baffles designed to exclude non-target species (DOC undated). Peanut butter was placed inside the box and the only way the rat had access to it was to go through the Spitfire tunnel. Once rats passed through the tunnel and the toxic paste was dispensed, their grooming behaviour, whether they ingested the paste, and the time to death were recorded for each animal.

Two Spitfire designs were trialled. The first model had a weight treadle to trigger the device and compressed CO_2 gas to propel the toxin once triggered; however, leakage of the CO_2 was a problem, and the weight trigger was difficult to weatherproof. A second model was designed that used a capacitance trigger and the propellant was liquid petroleum gas (LPG). The 1080 paste at a concentration of 0.55% was trialled in the Spitfires on both Norway and black rats.

Lure Trials

Urine and scats were collected by placing laboratory rats and black rats in metabolic cages for a few hours each day for 5 days (timed to include an oestrus cycle in the female rats). Samples were stored at -20°C. Urine and scats were collected from captive stoats by placing surgical swabs in their latrine area. Each rat treatment consisted of a sample of 0.5 ml of urine and 0.5 g of scats, compiled from 5 daily urine samples of 100 µl and 2 scat samples per day over the 5-day collection period. These were placed in a sterile petri dish inside the lure box. For the stoat treatment, a sample of swab from both a male and female stoat with urine and half a scat were placed in a sterile petri dish and placed in the lure box.

Lures were trialled on 4 wild Norway rats (2 females and 2 males) in an outdoor enclosure (2 × 4.5 × 2 m high). The pens were steam-cleaned between test animals and left vacant for 2 days. Test animals were placed in the pens 2 days before any trials to acclimatise. Two 1.2-litre black plastic boxes with holes drilled in them to allow air flow were placed randomly at either end of the outdoor pen and left overnight with the test rat. One box contained the test lure and the other was a control. Ltl Acorn trail cameras (Model Ltl-5210A, 940nm infrared, Ltl Acorn Outdoors, Denmark, WI, USA) were used to record interactions with the lure and control boxes. An interaction was defined as a rat sniffing and/or pawing the box. Four treatments were tested: Female Norway urine and scat; male Norway urine and scat; combined male and female black rat urine and scat; and combined male and female stoat urine and scat.

RESULTS

Toxin Trials

0.55% 1080 was lethal to rats when delivered in 800 mg of paste ejected by the Spitfire. Rats readily groomed the toxin from their bellies. 15/15 wild Norway rats and 14/15 black rats died. The black rat that survived may not have received a full dose of the toxin as the weight trigger was starting to malfunction. Trials on the last 6 black rats were undertaken with the new capacitance trigger and all died. Most Norway (53%) and black rats (86%) died overnight after being sprayed (Tables 1 & 2).

Table 1. Norway rats tested in the rat Spitfire containing 0.55% 1080 paste. Two models of the Spitfire were trialled, one with a weight trigger and the other a capacitance trigger.

Sex	Weight (g)	Trigger	Result	Time
F	227	weight	died	>24 h
F	179	capacitance	died	5 h 20m
F	141	capacitance	died	7 h 30 m
F	267	capacitance	died	overnight
F	278	capacitance	died	overnight
M	270	weight	died	overnight
M	306	weight	died	overnight
M	337	weight	died	overnight
M	249	weight	died	>24 h
M	249	weight	died	>24 h
M	294	weight	died	>24 h
M	311	capacitance	died	7 h 45 m
M	238	capacitance	died	overnight
M	252	capacitance	died	overnight
M	401	capacitance	died	overnight

Table 2. Black rats tested in the rat Spitfire containing 0.55% 1080 paste. Two models of the Spitfire were trialled, one with a weight trigger and the other a capacitance trigger.

Sex	Weight (g)	Trigger	Result	Time
F	105	weight	died	overnight
F	125	weight	died	overnight
F	133	weight	died	overnight
F	151	weight	died	overnight
F	156	weight	died	overnight
F	137	capacitance	died	overnight
F	156	capacitance	died	overnight
M	184	weight	died	4 h 30 m
M	154	weight	died	overnight
M	160	weight	died	overnight
M	150	weight	survived	
M	132	capacitance	died	overnight
M	145	capacitance	died	overnight
M	156	capacitance	died	overnight
M	168	capacitance	died	>24 h

Table 3. Interaction time (seconds) for 2female and 2 male Norway rats presented with 4 different lures and associated controls: Female Norway rat urine and scats; male Norway rat urine and scats; female and male black rat urine and scats; female and male stoat urine and scats.

Treatment	Norway Rats			
	Female 1	Female 2	Male 1	Male 2
F Norway	279	9	88	528
Control	46	1	3	24
M Norway	348	68	30	61
Control	118	3	8	80
F & M black rat	188	4	491	60
Control	100	0	41	150
F & M stoat	75	3	35	51
Control	27	0	37	45

Lure Trials

Preliminary trials indicated that the female Norway rat urine and scats were the most attractive to both female and male Norway rats (Table 3), with 86-97% of the total interaction time spent at the lure box compared to the control. Surprisingly, the urine and scats from stoats, a predator of rats, did not appear to act as a repellent.

DISCUSSION

The toxin trials with the Spitfire did confirm that rats will groom lethal levels of toxins from their bellies. The grooming response has been utilized previously to deliver a lethal dose to mammal pests, e.g., the use of rodent tracking powders. Building on that approach, Morris et al. (1983) developed a run-through tunnel with toxic wicks on the tunnel floor for rodent control, with intoxication from ingestion by grooming. The technique has obvious advantages where animals do not readily consume bait because of an abundance of alternative food or bait shyness. The advantage of the Spitfire is that it can deliver a measured amount of toxin to a pest and thus provide a high probability that a lethal dose is ingested. The consistency of the paste and the force at which it is sprayed by the propellant also ensure it does not drip and is less likely to contaminate the environment. In New Zealand, a controlled substance licence (CSL) is required to handle 1080, so although it would be a useful addition to the tool kit in a Spitfire for professional pest control operators, the ability to use toxins that do not require a CSL would be of particular benefit to community groups. Future trials will investigate using sodium nitrite, cholecalciferol, and brodifacoum in the Spitfire, as these toxins currently do not require a CSL when in bait formulations.

Resetting devices that are expected to work for long periods without being serviced also require long-life lures. Our preliminary trials showed that components of urine and scats from female Norway rats may hold promise as attractants to both female and male Norway rats; our sample size is small, however, and more trials are needed to confirm this finding. Zhang et al. (2008) found that female laboratory rats spent longer investigating male Norway rat urine than female urine in 3-minute choice tests, so the sex difference we found may be an artifact of our small sample size or the difference in methodology. Shapira et al. (2013) demonstrated that live laboratory Norway rats could act as lures to wild Norway rats but detected no significant differences in attractiveness based on the gender of the lure rats.

The 4 Norway rats trialed in this study showed no aversion to stoat urine and scats. Stoats are a predator of Norway rats (Innes 2005a) and predator odor has previously been shown to act as a repellant in some rat species, including Norway rats (for a review, see Apfelbach et al. 2005). A small number of recent studies however, have suggested that skin and fur-derived predator odors may have a more repellent effect on prey species than urine or scats, as a fur-related stimulus may indicate a higher level of threat (Apfelbach et al. 2005). In addition to increasing our sample sizes with the urine and scat lures, we will therefore be trialling bedding material. It is intended that the volatile components of the most attractive lures will be identified using headspace sampling and gas chromatographic analysis to aid in developing a liquid lure that could be incorporated into automated dispensing systems.

ACKNOWLEDGEMENTS

We wish to thank Jenn Bothwell and Jan Gill for animal husbandry, Robyn Blyth for helping with the trials, and John Dowding for reviewing a draft of the manuscript. The work described here was funded by the NZ Ministry of Business, Innovation and Employment. This research was undertaken with Lincoln University Animal Ethics Committee approvals #356, #502 and #503.

LITERATURE CITED

Apfelbach, R., C. D. Blanchard, R. J. Blanchard, R. A. Hayes, and I. S. McGregor. 2005. The effects of predator odors in mammalian prey species: A review of field and laboratory studies. Neurosci. Behav. Rev. 29:1123-1144.

Blackie, H., D. MacMorran, E. Murphy, D. Smith, and C. Eason. 2012. Integrating ecology and technology to create innovative pest control devices. Proc.Vertebr. Pest Conf. 25:274-276.

Cowled, B., P. Elseworth, and S. J. Lapidge. 2008. Additional toxins for feral pigs *(Sus Scrofa*) control: Identifying and testing Achilles Heel. Wildl. Res. 35(7):651-662.

DOC (Department of Conservation). Undated. Predator traps: Doc series trapping systems – Doc 200. Dept. of Conservation, Wellington, NZ. 4 pp. Available online.

Eason C. T., A. Miller, S. Ogilvie, and A. Fairweather. 2011. An updated review of the toxicology and ecotoxicology of 1080 in relation to its use as a pest control tool in New Zealand. NZ J. Ecol. 35(1):1-20.

Hix, S., P. Jansen, E. Murphy, L. Shapiro, D. MacMorran, and C. Eason. 2009. Stoat-Scratcher (Report No. 2) – Initial toxic pen trial report on the fully functioning prototype. Connovation report prepared for Northland Regional Council. 5 pp.

Hix, S., P. Aylett, L. Shapiro, D. MacMorran, C. T. Eason, S. Sam, J. G. Ross, A. Miller, and S. C. Ogilvie. 2012. Low-dose cholecalciferol bait for possum and rodent control. NZ J. Agric. Res. 55(3):207-215.

Innes, J. G. 2005a. Norway rat. Pp. 174-187 *in*: C. M. King, (Ed.), The Handbook of New Zealand Mammals. Oxford University Press, Melbourne.

Innes, J. G. 2005b. Ship rat. Pp. 187-203 *in*: C. M. King, (Ed.), The Handbook of New Zealand Mammals. Oxford University Press, Melbourne.

King, C. M., R. M. McDonald, R. D. Martin, D. I. MacKenzie, G. W. Tempero and S. J. Holmes. 2007. Continuous monitoring of predator control operations at landscape scale. Ecol. Manage. Restor. 8(2):133-139.

King, C. M., R. M. McDonald, R. D. Martin, and T. Dennis. 2009. Why is eradication of invasive mustelids so difficult? Biol. Conserv. 142:806-816.

McDonald, R., J-A. Short, L. Cate, K. Lyall, and R. Orchard. 1999. New technology for poison delivery. NZ J. Ecol. 23(2):289-292.

Morris, K. D., R. D. Proctor, and D. E. Kaukeinen. 1983. Design and evaluation for development of toxic wicks for rodent control. Pp.165-182 *in*: D. E. Kaukeinen (Ed.), Vertebrate Pest Control and Management Materials: Fourth Symposium. ASTM STP 817, American Society for

Testing and Materials, Philadelphia, PA.
Osada, K., M. Kashiwayanagi, and H. Izumi. 2009. Profiles of volatiles in male rat urine: The effect of puberty on the female attraction. Chem. Senses 34:713-721.
Parkes, J., and E. Murphy. 2003. Management of introduced mammals in New Zealand. NZ J. Zool. 30:335-359.
Shapira, I., U. Shanas, D. Raubenheimer, and D. H. Brunton. 2013. Laboratory rats as trap lures for invasive Norway rats: Field trial and recommendations. NZ J. Ecol. 7(2): 240-245.
Towns, D. R., and K. G. Broome. 2003. From small Maria to massive Campbell: Forty years of rat eradications from New Zealand islands. NZ J. Zool. 30:377-398.
Zhang, J-X., L. Sun, J-H Zhang, and Z-Y Feng. 2008. Sex- and gonad–affecting scent compounds and 3 male pheromones in the rat. Chem. Senses 33:611-621.