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Self-Resetting Traps Provide Sustained, Landscape-Scale Control of a Rat Plague in New Zealand

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ABSTRACT: Control of invasive mammals is central to the conservation and restoration of native habitats, especially in unique and vulnerable island ecosystems. While methods for eradication of pest mammals on offshore islands are well-established, long-term suppression at mainland sites and in other locations with an extremely high risk of re-invasion remains challenging. We examined the use of CO₂-powered, self-resetting traps for control of rats during a beech forest mast on the New Zealand mainland. Goodnature® A24 automatic traps installed on a 100 × 50-m grid reduced tracking indices for ship rats from 68% to 0% within a 200-ha area over a period of four months. The extent of the trapped area was then increased to 700 ha, with the resolution of the trapping grid reduced to 100 × 100 m. Tracking indices within the expanded area decreased from 44% to 0% within an additional two months. Activity of rats in a non-treatment site remained at around 70% for the duration of the project. Tracking indices for house mice decreased from 22% to 0% within four months and remained low for the duration of the project, indicating that non-targeted control of house mice was also achieved within the project area. Our results show that Goodnature® A24 self-resetting traps can successfully knock down and suppress rats from plague levels within an unprotected, mainland site.

KEY WORDS: automatic trap, invasive mammals, island biosecurity, New Zealand, *Rattus rattus*, rodent control, ship rat

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INTRODUCTION

Invasive mammals remain one of the most significant threats to biodiversity, especially in island ecosystems with a high level of endemism (Bellingham et al. 2010, Harper and Bunbury 2015). Ship rats (*Rattus rattus*) are a major predator of endemic species in New Zealand and are responsible for several local extinctions. Methods of eradicating rats from relatively small, isolated islands are well-established in New Zealand (Keitt et al. 2011, Blackie et al 2013), relying mainly on aerial toxicant delivery. However, the use of poison-based control remains problematic on the mainland. Re-establishment of rats at a mainland site occurs rapidly post-toxicant application, and a population needs to reach a minimum density before toxicant use becomes a cost-effective strategy for control on a landscape scale (Warburton and Thompson 2002). In addition, while toxicants have been employed successfully in New Zealand since the 1980s (Keitt et al. 2011, Blackie et al 2013), their use may be constrained internationally by risks to native mammal species (e.g., McIlroy 1992, Jolley et al. 2012), regardless of whether deployment is carried out aerially or with bait stations. Populations of invasive mammals in Europe and the Americas have established in habitats that support native species, including rats and other rodents (Leirs 2002) that would be vulnerable even to rodent-specific toxicants.

A high degree of specificity (i.e., whether a method can successfully target invasive species without harming non-targets, including humans and other mammals) is the most important consideration for any method of long-term pest control (Glen et al. 2013, Campbell et al. 2015). Trapping can be more species-specific than toxicant-based methods (Fraiser 2006). However, maintaining densities of invasive mammals that are low enough to

facilitate recovery of native populations requires frequent monitoring and re-baiting that may be prohibitive in terms of both financial expenditure and available person-hours (e.g., Franklin 2013, Glen et al. 2013). These constraints are leading to increased research investment in automatic trapping and toxicant delivery methods (Campbell et al. 2015).

Self-resetting traps led to significant decreases in rat activity, with positive results for predation of natives, compared to control using snap traps, in one Hawaiian study (Franklin 2013). In addition, sympatric pest populations of rats (*R. rattus*, *R. norvegicus*) and Australian brushtail possums (*Trichosurus vulpecula*) were controlled on a small, near-shore island in New Zealand using self-resetting traps (Carter et al. 2016). However, mainland populations of invasive mammals are still controlled using primarily toxicants. Our aim was to test the ability of toxicant-free, self-resetting mammal traps to control plague levels of rats within an unprotected mainland site. We also estimated the costs of attaining equivalent outcomes in a simplified scenario using two standard trapping methods as well as aerial and ground-based poisoning.

METHODS

Study Site

We established a trapping site adjacent to Harts Hill (45° 27' 30" E 167° 39' 00" S), an approximately 655-m peak within Fiordland National Park, a 1.2-million-ha World Heritage Area located on the South Island of New Zealand. Control of invasive mammal species is a high priority within the Park, which includes the historic habitat of several critically-endangered endemic species including the kākāpo (*Strigops habroptilus*), a flightless, nocturnal parrot, and the takahē (*Porphyrio hochstetteri*),

a flightless rail. The environment of the Park includes areas of native beech forest, of which Harts Hill is one, which undergoes temperature-cued, cyclical increases in seed production (i.e., mast events) every two to six years (Kelly et al. 2013), which precipitate plague levels of ship rats and house mice (*Mus musculus*). A control was established at Hidden Lakes, an environmentally comparable area of beech forest located approximately 15 km north of Harts Hill.

Trapping

We installed a network of traps (467 A24[®] rat + stoat traps, Goodnature[®] Ltd., Wellington, New Zealand) on a 100 × 50-m grid within a 200-ha area (i.e., a density of two traps per ha) (DOC 2006) during a beech mast event in November 2014. Traps were installed on tree trunks at a minimum height of 200 mm. In April 2015, the extent of the trapped area was increased to 600 ha, and the resolution of the trapping grid reduced to 100 × 100 m (i.e., 670 “A24” traps, installed at a density of one trap per ha) (Figure 1). Within the 600-ha area, traps were installed at (or raised to) a minimum of 700 mm to prevent interference by weka (*Gallirallus australis*), a flightless endemic rail. All traps were baited and pre-fed with a non-toxic, extended-life lure (Goodnature[®] Ltd.). Traps were checked and re-baited approximately every four weeks (requiring three person-days per check) from November 2014 to May 2015 during daylight hours.

Traps were powered by a 16-g canister of compressed

CO₂ gas that, when triggered, activates a steel-cored polymer piston that strikes the skull of the attracted pest and immediately re-sets (<http://www.goodnature.co.nz/index.php?pageID=how>). Rats are rendered irreversibly unconscious in <30 sec (Jansen 2011). The A24 trap is effective at targeting both rats and mice, and gas canisters can be fired at least 24 times before requiring replacement.

Monitoring

We established five lines of 10 tracking tunnels (Pest Control Research Ltd., Christchurch, NZ) and inked tracking cards (Black Trakka[®], Gotcha Traps, Auckland, NZ) at Harts Hill and the non-trapped control site (Gillies and Williams 2013). Monitoring was undertaken approximately every three months from November 2014, with tracking tunnels baited with peanut butter overnight, prior to each monitoring period. We estimated activity of rats, mice, and possums using tracking indices, with detection of rats and mice corrected for interference with the tracking cards by possums (Gillies and Williams 2013). A control was established at Hidden Lakes, an area of comparable beech forest located approximately 15 km from the study location. The locations of traps and tracking tunnels were plotted using ArcMap[™] Desktop v 10.2 software (Environmental Systems Research Institute, Redlands, CA, USA), using underlying geospatial layers downloaded from Land Information New Zealand (LINZ) Data Service (<http://www.data.linz.govt.nz>).

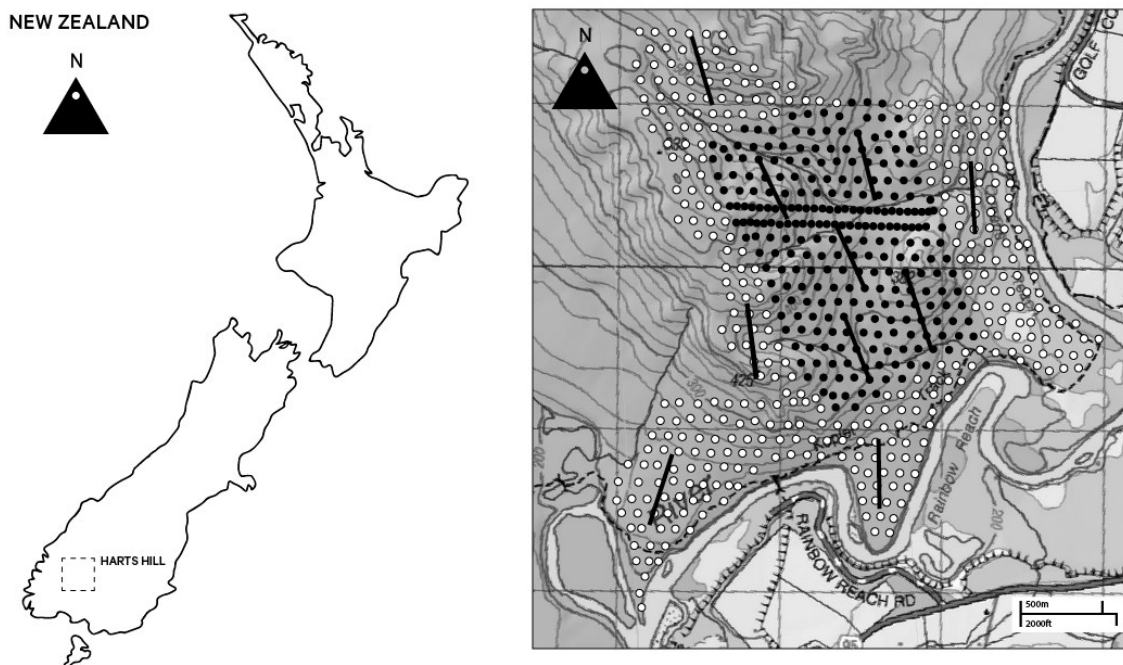


Figure 1. Map showing the grid of A24 traps and locations of tracking tunnel lines at Harts Hill, Fiordland National Park, relative to the entirety of mainland New Zealand. Traps installed within the initial 200-ha grid are indicated by solid black circles; the expanded, 600-ha grid is indicated by white circles. Tracking lines are in black.

Cost Estimation

We estimated the per-hectare costs of long-term suppression of rats using A24 traps, compared with four traditional methods. We based costs of establishing a network of traps or bait stations on current best-practice, including maintenance of the network over 10 years and a conservative annual device reliability rate of 98% (i.e., 2% requiring replacement per annum). For standard traps (DOC-200s and Victor[®] snap traps), we spaced traps at 50-m intervals along gridlines separated by 100 m. For self-resetting traps (Goodnature[®] A24s) and bait stations, we used a 100 × 100-m grid. Because self-resetting devices do not need to be serviced between kills, population knock-down can be achieved using a lower trap density. To provide a range of costs for each method, we used two scenarios: 1) a maximum-cost

scenario, in which cutting and marking of trap lines were completed separately from trap installation, with all work undertaken by contractors; and 2) a minimum-cost scenario, in which traps were installed and maintained entirely by volunteers along pre-existing lines.

We did not include the costs of project management, transportation of personnel, or pest monitoring. For bait stations, we averaged costs separately across first-generation (three bait types) and second-generation (two bait types) anticoagulants, including bait disposal costs but excluding the cost of obtaining resource consent for toxicant use. All costs were based on manufacturer-direct purchase, excluding tax, and converted based on the 1 March 2016 exchange rate of NZD = 0.6604 × USD (<http://www.rbnz.govt.nz/statistics/tables/b1>).

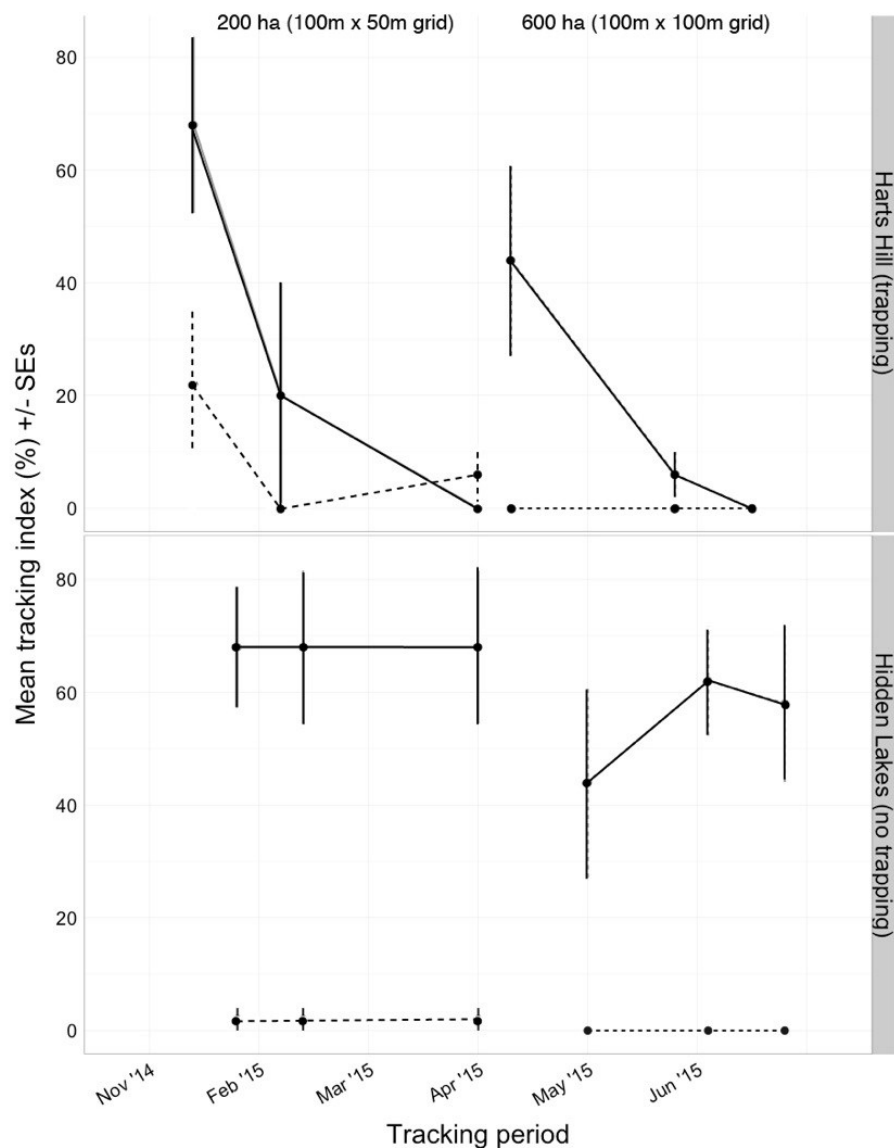


Figure 2. Summary of monitoring data from tracking tunnels at Harts Hill and from the control site at Hidden Lakes, with activity of ship rats indicated with a solid black line and activity of house mice indicated with a dashed line. The spacing of points is proportional to the amount of time between monitoring dates. Activity levels for rats are shown with the solid line, with activity levels for mice indicated with the dashed line.

RESULTS

Monitoring

At Harts Hill, tracking indices for rats decreased from 68% (+/- 16%) to 0% between November 2014 and February 2015. Tracking indices within the 600-ha site decreased from 44% (+/- 17%) to 0% between April and June 2015 (Figure 2), then increased to 1% in July 2015. Tracking indices for house mice decreased from 22% (+/- 12%) to 0% between November 2014 and February 2015. Tracking indices for house mice within the 600-ha trapped area remained at 0% (Figure 2). Tracking indices for possums increased from 0% to 4% between November 2014 and February 2015. Tracking indices for possums within the 600-ha trapped area increased from 0% to 12% between April and June 2015.

At the control site, tracking indices for rats remained at 68% (+/- 11-14%) between November 2014 and February 2015. Between April and June 2015, tracking indices for rats varied between 44% (+/- 17%) and 62% (+/- 10%) (Figure 2). Tracking indices for house mice decreased from 2% to 0% between November 2014 and February 2015 and remained at 0% throughout the control operation (Figure 2). Tracking indices for possums increased from 2% to 6% between November 2014 and February 2015, then remained between 0-2% for the remainder of the control operation. Since possum activity remained low throughout the control operation, observed activity levels of rats and mice should not be confounded by possum interference.

Cost Estimation

The accumulated per-hectare costs of installing self-resetting traps for knockdown and suppression of rats were generally higher than the other methods we examined, except for DOC-200 traps and Victor® snap traps (after 7 years). However, the \$20 per hectare annual maintenance costs for A24 traps were equal to those of second-generation anticoagulants and slightly lower than those for first-generation anticoagulants, when maintenance was undertaken by contractors (Table 1).

DISCUSSION

Both knockdown and long-term suppression of invasive mammals are critical for facilitating recovery of native populations. Suppression of mainland pest populations requires the capacity to stay ahead of their recovery, which can occur rapidly through breeding of newcomers from adjacent populations. We found that Goodnature A24 traps can simultaneously knock down and control invasive rats and mice within a mainland site during a beech mast event that would, under non-trapped conditions, precipitate plague levels of both. Our results confirm previous research showing that self-resetting traps can control sympatric populations of pest mammals in a location with a high potential for re-invasion (Carter et al. 2016). Even though mice were not explicitly targeted in this study, the sustained suppression of rats and mice to activity levels of 0-1% improves on outcomes obtained previously, using either self-resetting traps (Carter et al.

Table 1. Estimated, per-hectare costs of suppressing ship rats (rounded to the nearest \$1.00), using A24 traps vs. two best-practice trapping methods and two toxicant-based methods, accumulated over 10 years from installation in year 0. The maximum-cost scenario includes separate cutting and marking of trap lines and trap installation, with all work undertaken by contractors, at a current rate of \$66.04 per ha. The minimum-cost scenario assumes lines are pre-existing, with all traps installed and maintained by volunteers using \$5.20 per ha in consumables. Trap costs are: \$85.85 per ha for A24s (one trap), \$87.17 per ha for DOC-200s (two traps + tunnels), \$20.21 per ha for Victor® snap traps (two traps + tunnels), and \$8.26 per ha for bait stations (one station). Year-zero costs for DOC-200s and snap traps include \$33.02 per ha for helicopter transport, required for remote sites due to trap weight, while a single contractor or volunteer can carry 30+ A24s into a site. Costs higher than those estimated for A24 traps after a comparable amount of time are highlighted in gray.

	A24 Traps		DOC-200 Traps		Victor Traps		1st Gen Anticoagulants		2nd Gen Anticoagulants	
	\$ min	\$ max	\$ min	\$ max	\$ min	\$ max	\$ min	\$ max	\$ min	\$ max
0	91	171	125	215	25	125	13	87	13	87
1	101	191	127	243	26	151	25	113	19	107
2	111	211	129	271	27	177	37	139	25	127
3	121	231	131	299	28	203	49	165	31	147
4	131	251	133	327	29	229	61	191	37	167
5	141	271	135	355	30	255	73	217	43	187
6	151	291	137	383	31	281	85	243	49	207
7	161	311	139	411	32	307	97	269	55	227
8	171	331	141	439	33	333	109	295	61	247
9	181	351	143	467	34	359	121	321	67	267
10	191	371	145	495	35	385	133	347	73	287

2016) or traditional methods, including toxicant-based or combined methods (e.g., Gillies et al. 2003, Gillies et al. 2006).

Tracking indices of mice remained very low at the control site throughout the study. However, because activity of mice did not increase within the trapped site following the initial knockdown of rats, we can conclude with more confidence that the suppression of mice at the trapped site can be attributed to the use of self-resetting traps. In addition, the knockdown and suppression of rats did not lead to an increase in mouse activity, even during a beech mast, which supports the conclusion that the use of self-resetting traps for control of rats should not precipitate competitor release. In locations that support populations of invasive rats and mice, a grid of A24 traps should effectively reduce densities of both to levels that can allow for recovery of native species.

Our cost estimation showed that when trap maintenance was carried out by paid contractors, the use of A24s for control of rats and/or mice was less expensive than most other methods. Critically, the ongoing maintenance costs for A24s were estimated to be lower than those of both the single-set trapping methods we examined. Thus, overall costs for deployment of a trapping grid are likely to be lower if self-resetting traps are used in lieu of single-set devices. We did not include person-hours explicitly in our cost model. However, Franklin (2013) reported that A24 traps were more cost-effective in terms of labor hours, compared to single-set snap-traps, for suppression of rats in Hawaiian forest habitat. Even though our estimated financial costs of using A24s were higher when work was carried out by volunteers, the reduction in paid labour hours would allow for management of invasive mammals to be undertaken within a larger area. In addition, while the high humaneness rating (Jansen 2011), especially relative to toxicant-based methods of suppression, and low environmental impact of self-resetting traps, compared with toxicant deployment, cannot be modeled in economic terms, both factors may be beneficial for increasing public acceptance of invasive mammal control.

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