Testing auto-dispensing lure pumps for incursion control of rats with reduced effort on a small, re-invadable island in New Zealand

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Abstract In locations with a high potential for re-invasion, such as inshore islands, sustained control of invasive species is as important as the initial knock-down for the long-term recovery of native populations. However, ongoing trap maintenance and lure replenishment are barriers to minimising the time and financial costs of long-term suppression, even when automatic traps are used. Control of invasive mammal species is a high priority for the more than 200 islands within Rakiura National Park in southern New Zealand, many of which support nationally and internationally threatened endemic species and ecosystems. We previously used automatic, toxicant-free traps to control rats on Native Island, a 62 ha inshore island within the National Park, where tracking indices were 73% in mid-2013. After 18 months, tracking indices remained below 10%, and site visits were reduced to twice per year, following introduction of novel auto-lure pumps. Tracking indices for rats remained low after six months, then increased to 37% in May 2017. That increase, as well as small fluctuations in measured activity levels throughout the study, could indicate continued incursion from the mainland, highlighting the importance of continued suppression. Additional work is needed to determine the limitations of the automatic lure dispensers and optimise their use for long-term suppression of pest mammals in ecosystems that are highly vulnerable to re-invasion.

Keywords: conservation, invasion biology, invasive mammals, island biosecurity, Norway rat (*Rattus norvegicus*), Pacific rat (*Rattus exulans*), ship rat (*Rattus rattus*)

INTRODUCTION

Introduced mammals are one of the most significant threats to island ecosystems (Towns, et al., 2006; Bellingham, et al., 2010; Harper & Bunbury, 2015). In particular, rats (*Rattus* spp.) and other rodents have become major predators of endemic island species, causing several local extinctions (Courchamp, et al., 2003; Towns, et al., 2006; Bellingham, et al., 2010). Thus, they are a main target of eradication operations (Howald, et al., 2007; Glen, et al., 2013; Holmes, et al., 2015). However, while numerous offshore rat eradications have been undertaken successfully since the 1980s, eradication is more difficult in locations that are close enough to a non-controlled pest population to facilitate rapid, and inevitable, re-invasion (Russell, et al., 2008; Nathan, et al., 2015). At highly re-invadable sites, such as near-shore islands, a single operation can theoretically eliminate a population of invasive rats. However, that 'eradication' is only temporary. Sustained control is required in order to prevent re-establishment (Simberloff, 2011), which can occur rapidly and with only a few invaders (Russell, et al., 2008; Nathan, et al., 2015).

Most successful eradication operations on New Zealand islands – both of rats and of other pest mammals – have been undertaken using site-wide toxicant applications (Blackie, et al., 2013; Keitt, et al., 2015). However, toxicant-based methods are not as effective for sustained control in highly re-invadable sites as they are on relatively isolated, offshore islands. Importantly, a re-invading population of mammals has to achieve a minimum density in order for repeated toxicant use to be considered a cost-effective means of control (Warburton & Thomson, 2002), but that density threshold is higher than the maximum density under which many native species can successfully recover (Gillies, et al., 2003; Norbury, et al., 2015). Thus, conservation-motivated, long-term mammal suppression in re-invadable sites requires the availability of sustained-use, cost-effective methods. Throughout this paper, we use the terms 'suppression' and 'maintenance control' interchangeably to refer to any control method used to prevent the re-establishment of a population of pest mammals in an island due to incursion. However, the same principles can be applied within any controlled area that is at risk of being invaded, or re-invaded, from an adjacent, un-controlled population.

Unlike mammal control operations that rely on site-wide application of toxicants, traps can be left in situ and used for incursion control. However, current best-practice methods of trapping require continual re-baiting and, if a trap is triggered, re-setting of the trapping mechanism to remain effective (DOC, 2006). In addition, traps may be less effective at controlling low-density populations than they are at eradication of established, high-density populations (Thorsen, et al., 2000; Chappell, 2004). As a result, effective island biosecurity still requires regular surveillance and the availability of funding to undertake contingency response in the event of an incursion (Russell, et al., 2008). A relatively new technique for long-term control of invasive mammal populations is the use of automatic, or self-resetting, trapping and toxicant application mechanisms (reviewed in Campbell, et al., 2015). Like single-use trapping methods, self-resetting mechanisms – both traps and toxicant-delivery devices – can be designed with relatively high specificity, reducing the rate of non-target kills, relative to that realised following site-wide toxicant applications (Campbell, et al., 2015). Unlike single-use traps, automatic mechanisms can remove multiple pests before requiring maintenance and/or re-baiting (Blackie, et al., 2011; Blackie, et al., 2013; Murphy, et al., 2014; Carter, et al., 2016).

Automatic toxicant-delivery devices have been designed for stoats (*Mustela ermina*), possums (*Trichosurus vulpecula*) (Blackie, et al., 2016) and rats (Blackie, et al., 2013; Murphy, et al., 2014). Automatic, toxicant-free traps and corresponding long-life lures have been developed by Goodnature® Ltd for possums, rats, and stoats (Carter, et al., 2016; Carter & Peters, 2016), with the advantage that devices that do not rely on poisons may be more acceptable for control of invasive mammals in locations that support populations of native mammals (Campbell, et al., 2015). Self-resetting traps have been used to control sympatric populations of Norway rats (*Rattus norvegicus*), ship rats (*R. rattus*), and Australian brushtail possums

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on a single, near-shore island (Carter, et al., 2016) and to control ship rats and mice (*Mus musculus*) within an unprotected mainland site (Carter & Peters, 2016) in New Zealand. One pest control operation in Hawaii also found that automatic traps were more beneficial for decreasing predation of native species by rats than single-action snap-traps (Franklin, 2013).

The long-term financial costs of using automatic traps for control of invasive mammal populations are comparable to those of using basic Victor® snap-traps, especially when work is undertaken primarily by contractors, and slightly lower than the costs of using DOC-200 traps, heavy-duty, single-action tunnel traps commonly used for maintenance control (Carter, et al., 2016; Carter & Peters, 2016). The use of self-resetting traps greatly reduces the frequency at which site visits must be undertaken, relative to traditional methods of trapping that require regular rebaiting and resetting to maintain effectiveness (e.g., Franklin, 2013). However, the rate at which even long-life lures must be replenished in self-resetting traps – approximately monthly – is still higher than the rate at which pests are killed, following initial suppression of the population (Carter, et al., 2016). As a result, the costs of long-term suppression of pest mammals – in terms of both equipment and person-hours – are increased significantly by the investment in on-the-ground trap maintenance, even when self-resetting traps are used (Franklin, 2013; Glen, et al., 2013; Carter, et al., 2016; Carter & Peters, 2016).

The continued effectiveness of self-resetting traps relies largely on maintaining attractiveness of the highly viscous lure, which is contained within a plastic bottle housed inside the trap. When a targeted mammal population is relatively dense and the lure is consumed regularly, the force of gravity is sufficient to keep 'fresh' lure available. Once a population of invasive mammals has been knocked down, human intervention is required to ensure that un-eaten lure does not become mouldy and unpalatable after being exposed to air. Thus, the mechanism of lure delivery itself remains a barrier to minimising costs of maintenance control. Here, we tested the use of auto-dispensing lure pumps for retaining lure freshness and maintaining low levels of rats on a previously-controlled inshore island, while significantly reducing the person-hours required for undertaking site visits.

MATERIALS AND METHODS

In November 2013, we installed 143 CO_2-powered, automatic rat traps (A24; Goodnature® Ltd, Wellington, New Zealand; https://www.goodnature.co.nz) on a 100 m × 50 m grid on Native Island (46°54'54″ E 168°09'25″ S) (Carter, et al., 2016), a mostly forested, 62 ha Scenic Reserve within Rakiura National Park in southern New Zealand (DOC, 2012). Because Native Island sits approximately 100 m from the coast of the main island of Stewart Island (also known as Rakiura), incursion by multiple species of pest mammals from the mainland following a control operation is inevitable (Atkinson, 1986). The presence of Norway rats, ship rats and brushtail possums has been confirmed on Native Island (DOC, 2012), and all three species were observed during establishment of the trapping network. In addition, Pacific rats (kiore, *Rattus exulans*) are present on the nearby mainland and may pose an additional incursion risk.

Each trap was initially baited with a bottle of non-toxic, peanut-based lure and checked approximately monthly, with lure bottles and CO_2 cartridges replenished every six months (Carter, et al., 2016). Due to lack of resources, the traps were not maintained for the eight months between September 2015 and May 2016. In May 2016, we replaced all CO_2 cartridges and replaced the standard lure bottles with novel auto-lure pumps. The auto-lure pump is a soft-sided lure bottle that uses hydrogen gas expansion to deliver 55 g of non-toxic lure over a period of six months (Fig. 1). The CO_2 cartridges and auto-lure pumps were replaced every six months.

During the initial control operation only, we used tracking tunnels (Pest Control Research [PCR] Ltd., Christchurch, New Zealand) with inked tracking cards (Black Trakka®, Gotcha Traps, Auckland, New Zealand) to monitor mammal activity within the trapping grid on Native Island and at a control site, located 3.5 km away on Stewart Island (Gillies & Williams, 2013). We estimated rat activity using tracking indices, with detection corrected for interference with the tracking cards by possums, where required (Gillies & Williams, 2013). Tracking tunnels were installed at 50 m intervals on Native Island in six lines of five tunnels each, and at the control site in three lines of five tunnels and two lines of ten tunnels. During each monitoring period, tracking tunnels were baited with peanut butter and tracking cards retrieved after 24 hours (Carter, et al., 2016). Following installation of the auto-lure pumps, rat activity was monitored at two subsequent intervals of approximately six months, at the Native Island site only.

RESULTS

During the initial control operation, tracking indices for rats on Native Island decreased from 73% to 7% within nine months of initiation of trapping and remained perpetually at or below 10% during the monitoring

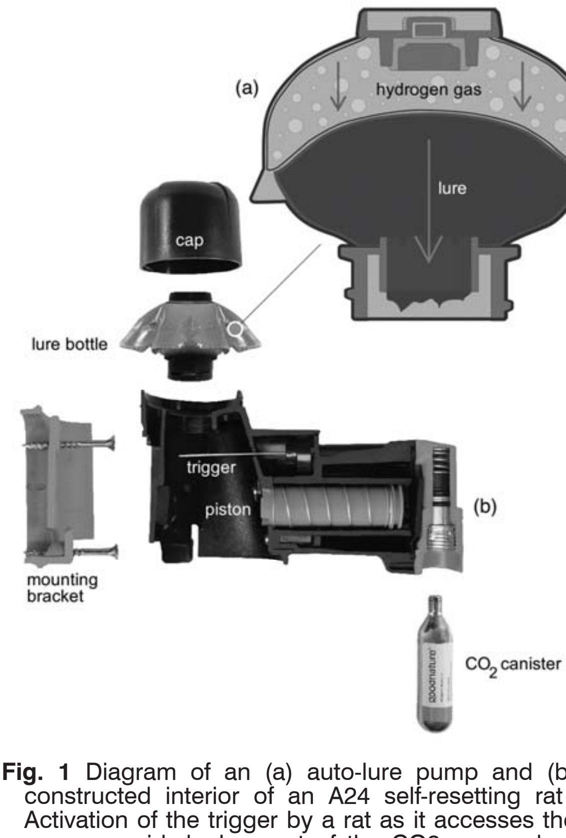

Fig. 1 Diagram of an (a) auto-lure pump and (b) de-constructed interior of an A24 self-resetting rat trap. Activation of the trigger by a rat as it accesses the lure causes rapid deployment of the CO2-powered piston, which strikes the skull and results in near-instantaneous death. The trap automatically resets after each strike, up to 24 times. Gradual expansion of hydrogen gas inside the soft-sided, auto-lure pump slowly delivers lure through the bottle opening over a period of six months. Image courtesy of Goodnature® Ltd (Wellington, New Zealand).

period, while tracking indices at the control site remained comparatively high (Fig. 2; see Carter, et al., 2016 for complete results). On the first monitoring visit following installation of the auto-lure pumps, tracking indices on Native Island were 7% but increased to 37% during the most recent site visit in May 2017 (Fig. 2). Rat activity was not monitored at the control site after the initial trapping operation. However, tracking indices within a separate, untrapped area on Stewart Island were 40% in March 2017 (SIRCET, 2017). Between the first and second monitoring visits, air temperatures were between -1.5°C and 0.5°C of monthly regional (Southland) averages, varying between 8°C and14°C during the study months (Macara, 2013), and rainfall levels were at or below normal levels (Fig. 2).

DISCUSSION

This project was the first *in situ* test of auto-dispensing lure bottle technology, following a previous knockdown. One of the primary motivations for developing time-saving technologies for invasive mammal control – lack of sufficient available person-hours for maintaining traps and monitoring for incursions – was both the impetus for and the main limitation of this study. Because rat activity levels were not monitored for the year prior to installation of the auto-lure pumps, nor when they were installed, we cannot say definitively that they were as effective as standard lure bottles at maintaining low levels of rats. That is, the activity levels recorded in October 2016 could be indicative of no incursions, with switching of standard bait bottles for auto-lure pumps having no effect on the consistently low activity levels observed since at least August 2014. However, given the proximity of the study site to uncontrolled populations of multiple rat species, as well as fluctuating activity levels throughout the original control operation and slight increase observed in May 2015, that activity levels were still below 10% a year later is unlikely. More likely is that rat activity levels increased to some extent prior to installation of the auto-lure pumps and that the pumps effectively reduced activity levels during the first five months of their operation.

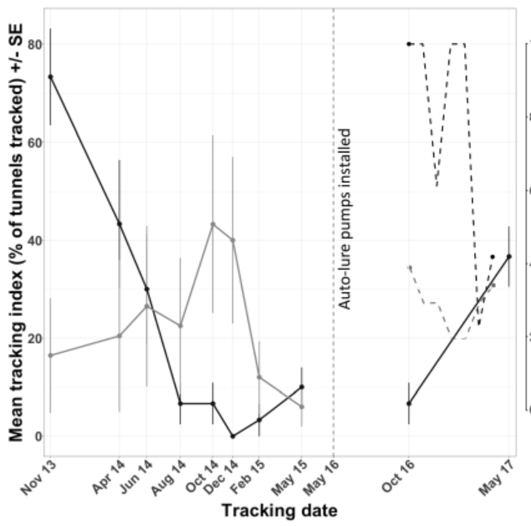

Fig. 2 Summary of monitoring data from tracking tunnels on Native Island (black) and the control site on Stewart Island (grey), with the introduction of auto-lure pumps indicated by the dashed vertical line. Except for the period from May 2015 – May 2016, the spacing of x-axis labels is proportional to the amount of time between monitoring dates. The percentage of tracking cards with interference by possums was high at the control site on Stewart Island throughout the initial trapping operation, so true activity of rats may be higher than indicated by the plot, especially in February and May of 2015. No data are available for the period May 2015 – October 2016, and no monitoring was undertaken at the control site after May 2015. Climate data are shown with dashed lines. The rainfall axis shows the approximate percentage of local rainfall in each month, relative to 'normal' conditions (i.e., a value of 100% is equal to normal). The temperature axis shows the deviation of local air temperatures from average conditions, with a value of 0 equal to the respective monthly mean. Weather information was obtained from NIWA 'Current climate' monthly summaries (https://www.niwa.co.nz/climate/nzcu/). Plot adapted from Carter, et al. (2016).

During the second, but not the first, monitoring visit to Native Island, the lure was noticeably mouldy and may have been less attractive to rats. Mould growth may be related to environmental conditions at the study site, which would suggest that the rate of gas expansion inside the auto-lure pump may be insufficient to keep the lure fresh in certain conditions. Climate has been implicated in the failure of mammal control operations across methods, with stationary bait stations being most similar to trapping. Bait station-based eradication failures have been associated with higher mean annual temperatures and increased variation in inter-annual precipitation in tropical locations, which become more important with increasing island size (Holmes, et al., 2015). High temperatures, in particular, are a significant predictor of failure across toxicant-based methods of rat eradication (Holmes, et al., 2015).

The importance of climate to the success of mammal control has been examined primarily in relation to the timing of toxicant application, particularly in the tropics, where more consistent food availability increases the difficulty of targeting rodents using attractant-based toxicants (Holmes, et al., 2015; Russell & Holmes, 2015). Air temperatures at our study location did not vary much from average monthly conditions, and more months were relatively 'dry' than 'wet,' compared with regional norms (Fig. 2). However, further research should be undertaken to determine whether abiotic environmental conditions constrain the efficacy of auto-lure pumps. If so, either (1) increasing the rate of gas expansion inside the auto-lure bottle or (2) increasing the rate of site visits during particular seasons or in climates normally conducive to mould growth may be required.

Assuming the number of successful control operations in incursion-vulnerable sites increases, so too will the costs of controlling invasive mammals. In highly re-invadable sites, true eradication is an impractical aim (Simberloff, 2011). Indeed, if mammal densities can be maintained at levels low enough to facilitate the recovery of native populations, then eradication becomes less immediately imperative. Thus, cost-effective suppression of pest mammals is a realistic goal for conservation of endemic island biodiversity. Technologies that minimise the time and financial investments required for long-term control will be key to maximising the area within which populations of invasive mammals can be controlled. More work is needed to optimise the use of auto-lure pumps and quantify their limitations. However, effective automatic lure delivery devices would be a transformative addition to the pest-control toolbox and should continue to be rigorously developed and tested.

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