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Special Issue: Effectiveness of Goodnature A24 self-resetting rat traps for invasive rodent control
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Editorial

An introduction to a special issue and review of the effectiveness of Goodnature A24 self-resetting rat traps

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Abstract

Rodent pest species threaten many of the world's resources, including those in agriculture, urban, and natural environments. Goodnature® A24 rat+stoat self-resetting traps (A24s) are used extensively for invasive rat control in several countries and environments, especially in island ecosystems. Unlike traditional single-set kill traps, A24s fire and reset up to 24 times per CO_2 cartridge, and represent a nontoxic device for rodent pest control. Given the rapid rise in use of A24s as a management tool, our goal was to understand why A24s work in some cases and not others. To address this goal, we briefly review A24 literature, and then we: 1) introduce a special issue of A24 effectiveness and hazard studies, and 2) propose future research needs and recommended uses for A24s including a list of potentially susceptible rodent species for which further A24 testing is required. Most papers in the special issue focus on *Rattus rattus* control on islands in Hawaii and New Zealand. Additionally, A24 effectiveness was compared to toxic bait use against rats in California agricultural landscapes, and snap-traps against house mice (*Mus musculus*) in Colorado pens. Behavioral studies in this special issue demonstrated that both rats and mice repeatedly visit and pass by A24s much more frequently than they trigger A24s. Some large-scale trapping grids in Hawaiian forests reduced rat populations, but a few endangered birds were unintentionally killed by A24s, which stimulated research on bird excluder attachments for A24s. Understanding the duration of carcass persistence of rats and birds killed by A24s has helped trap users account for unobserved target and non-target kills. Future research may investigate A24 uses on rodent species other than *Rattus*, as the types of species potentially vulnerable to A24s range in size from mice (e.g., *Apodemus, Mus, Peromyscus, Reithrodontomys*; ≥ 14 g) to squirrels (e.g., *Otospermophilus*, *Sciurus*; 353–527 g). A24s can be used successfully to control rodent populations of some species in particular environments. Studies that compare A24s with alternative and synergistic rodent management methods will help determine the most effective and efficient rodent control methods that minimize non-target risks.

Key words: automatic self-resetting traps, body size vulnerability, invasive mammal trapping, nontoxic rodent pest control, *Mus musculus*, native- non-native management, *Rattus* spp.

Introduction

Managing invasive rodents has been perpetually viewed as an important practice to protect biodiversity, agriculture, and human health and safety (Prakash 1988; Witmer and Shiels 2018). Goodnature® A24 rat+stoat self-resetting traps (hereafter A24 or A24s) are used extensively for invasive rat (*Rattus* spp.) control in several countries and environments, especially on islands (Carter et al. 2016; Shiels et al. 2019; Gronwald and Russell 2022; Baldwin et al. 2022; Table 1). Stoat (*Mustela erminea* Linnaeus, 1758) trapping with A24s has been documented in New Zealand, but generally other methods of stoat control have been used more frequently than A24s (Gillies et al. 2014). Unlike traditional single-set kill traps, A24s trigger and reset up to 24 times per CO_2 cartridge, and represent a nontoxic and humane device for rodent pest control. The multi-kill component of the A24 is associated with a CO_2 cartridge that powers a piston directed at the head of a rat or stoat triggering the trap. Once impact occurs, the piston automatically self-resets and the impacted animal drops to the ground, leaving the trap entrance unobstructed so another target species can enter the trap. Thus, key features that Goodnature claim make A24s particularly attractive for pest rodent control include the self-resetting and self-clearing design, a long-life lure (e.g., Goodnature chocolate lure) that can maintain attractiveness for up to 4–6 months (Bogardus and Shiels 2020), and the absence of toxicants that could result in secondary contamination (https://goodnature.co).

A24s are not species-specific traps, meaning that other (non-target) small animals besides the target rat or stoat may access the trigger and be injured or killed by the trap. Examples of non-target kills reported from A24s deployed in the field in New Zealand include: hedgehogs (*Erinaceus europaeus* Linnaeus, 1758), European rabbits (*Oryctolagus cuniculus* Linnaeus, 1758), a juvenile paradise shelduck (*Tadorna variegata* Gmelin, 1789), rifleman (*Acanthisitta chloris* Sparrman, 1787), tui (*Prosthemadera novaeseelandiae* Gmelin, 1788), North Island robins (*Petroica longipes* Garnot, 1827), and weta (Anostostomatidae or Rhaphidophoridae) (Gillies et al. 2014). Up to five puaiohi (*Myadestes palmeri* Rothschild, 1893), a federally endangered forest bird on Kauai Island, Hawaii, were killed by A24s during rat trapping (Kreuser et al. 2022; Crampton et al. 2022), and one quenda (bandicoot; *Isoodon obesulus* Shaw, 1797) was killed in Australia while targeting pest rats (Davis 2022). House mice (*Mus musculus* Linnaeus, 1758) in New Zealand and Hawaii (Gillies et al. 2014; Coad et al. 2017; T. Bogardus *unpublished data*), and mongoose (*Herpestes auropunctatus* Hodgson, 1836) and Erckel's francolin (*Francolinus erckelii* (Ruppell, 1835)) in Hawaii (T. Bogardus *unpublished data*), are additional invasive vertebrates that have been killed by A24s during field operations targeting rats. Unlike classic snap-traps where animals access the bait and the trap along an uncovered

Table 1. Studies of A24s targeting rats (*Rattus* spp.). A24s were originally designed for use against the three *Rattus* species listed, yet most of the uses and studies have targeted *R. rattus* (black, roof, ship rat) rather than *R. norvegicus* (brown, Norway rat) or *R. exulans* (kiore, Pacific, Polynesian rat). A24 effectiveness was judged by ability of A24s to attract and kill rats or suppress rat populations. When rat body sizes were unavailable for the associated study (e.g., many field studies), a reference that included body size data from a nearby location was provided. An asterisk denotes a study that is part of this special issue of *Management of Biological Invasions*.

Rodent species	Size range (g)	Purpose of use	Lab or field assessments? (site & country performed)	A24 effective?	Reference
R. rattus	110–180	Original humaneness trials	Field (North Island, NZ)	Yes, killed 10 of 10 within 30 seconds since impact	Jansen (2011)
R. rattus	54–212 (adult sizes based on Innes 2005b)	Field test the early A24 traps to ensure mechanical functionality	Field (North Island, NZ)	Yes, killed some rats and stoats	Gillies et al. (2012)
R. rattus	74–200 (adult sizes based on Shiels 2010)	Reduce rat population to benefit native & endangered species	Field (Oahu Island, USA)	Yes, rat populated reduced at one site	Franklin (2013)
R. rattus	54–212 (adult sizes based on Innes 2005b)	Field test the early A24 traps with and without an auto-lure to test for population reduction	Field (North Island, NZ)	Yes, reduced rat population in one season with auto-lure; and No, did not reduce rat population in season without auto-lure	Gillies et al. (2014)
R. rattus	83–199 (adult sizes based on Innes 2005b)	Reduce rat population	Field (South Island, NZ)	Yes, reduced rat population	Carter and Peters (2016)
R. rattus	103–306 (adult sizes based on Innes 2005a)	Reduce two *Rattus* species' populations	Field (Native & Stewart Islands, NZ)	Yes, reduced rat populations	Carter et al. (2016)
R. rattus	74–200 (adult sizes based on Shiels 2010)	Field test A24 traps to ensure mechanical functionality	Field (Hawaii Island, USA)	Yes, killed some rats & rat activity anecdotally decreased	Coad et al. (2017)
R. rattus	52–210 (adult sizes based on Innes 2005a)	Reduce two *Rattus* species' populations	Field (Great Barrier Island, NZ)	No, not likely, as it killed rats but did not reduce rat populations	Gilbert (2018)
R. rattus	74–200 (adult sizes based on Shiels 2010)	Reduce rat population to benefit endangered species	Field (Oahu Island, USA)	Yes, most likely, as rat population was reduced using A24s & snap traps	Shiels et al. (2019)
R. rattus	74–200 (adult sizes based on Shiels 2010)	Reduce rat population to benefit native & endangered species	Field (Oahu Island, USA)	Yes, rat populated reduced at three sites	Bogardus and Shiels (2020)
R. rattus	74–200 (adult sizes based on Shiels 2010)	Reduce rat population to benefit endangered seabirds	Field (Kauai Island, USA)	Yes, most likely, as seabird depredation by rats was reduced using A24s & 3 other trap types	Raine et al. (2020)
R. rattus	52–210 (adult sizes based on Innes 2005a)	Reduce rat population to benefit native species	Field (Goat Island, NZ)	Yes, rat population was reduced using A24s & DOC200 traps	*Gronwald and Russell (2022)
R. rattus	74–200 (adult sizes based on Shiels 2010)	Reduce rat population to benefit native & endangered species	Field (Kauai Island, USA)	Yes, rat population was reduced for multiple years	*Crampton et al. (2022)
R. rattus	160–205 (adult sizes based on Jameson and Peeters 2004)	Reduce rat population to benefit citrus crop	Field (California, USA)	No, did not reduce rat population at four sites studied	*Baldwin et al. (2022)
R. norvegicus	Unknown	Original humaneness trials	Lab (UK)	Yes, killed 10 of 10 within 3 minutes since impact	R. van Dam, *pers. comm.*
R. norvegicus	103–306 (adult sizes based on Innes 2005a)	Reduce two *Rattus* species' populations	Field (Native & Stewart Islands, NZ)	Yes, reduced rat populations	Carter et al. (2016)
R. exulans	25–80	Test trap efficacy in setting with high rat density where this is only rat species on the island	Field (Wake Island, USA)	No, rats did not enter inside of traps & only visited outside of traps	A.B. Shiels, *unpublished data*
R. exulans	47–145 (adult sizes based on Atkinson and Towns 2005)	Reduce two *Rattus* species' populations	Field (Great Barrier Island, NZ)	No, not likely, as it killed *R. exulans* but <10% of the local estimate population	Gilbert (2018)

surface, A24s consist of intersecting vertical and horizontal cylinders (Figure 1). To reach the bait and triggering components of the A24, animals gain access to the open bottom of the vertical cylinder and scale the

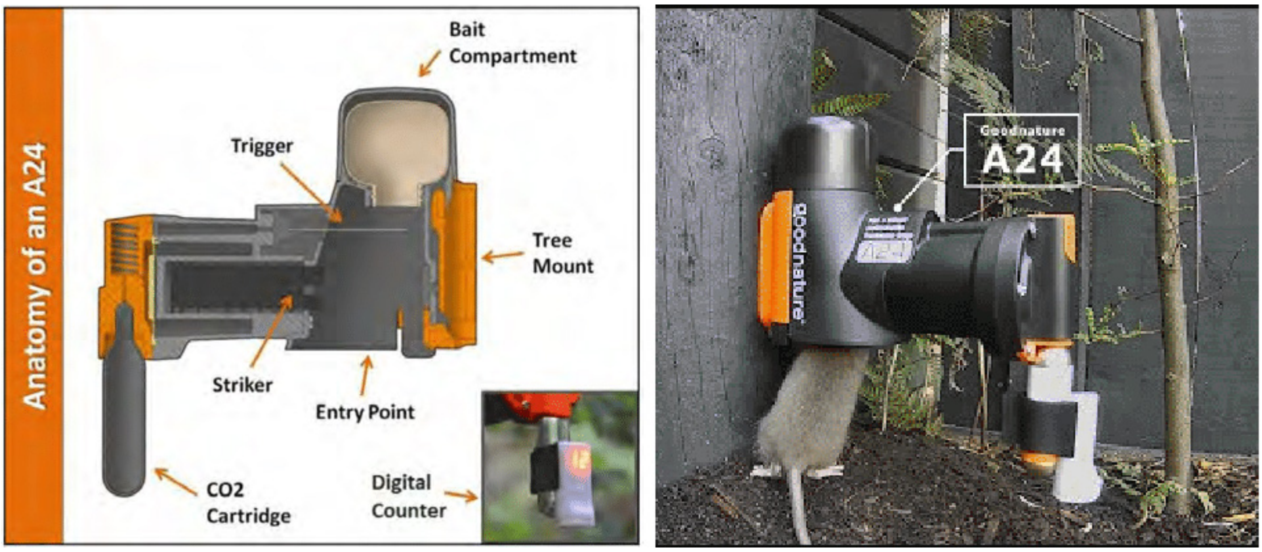

Figure 1. Goodnature A24 rat+stoat trap showing each component (left picture) and with a rat beginning to scale the inner vertical cylinder of the trap to reach the trigger and lure (right picture). Pictures accessible at https://goodnature.co.

inside of it. A24s are therefore designed to exclude many types of non-target species, which is a benefit, but it may also deter some targeted individuals from entering this novel device (e.g., suggested in Gilbert 2018).

Currently there are thousands of A24s deployed in New Zealand and Hawaii, and our recent count of A24s in Hawaii alone is ~ 3,300. Over the last decade, A24 effectiveness for invasive rat control has been variable (Gillies et al. 2012, 2014; Carter et al. 2016; Gilbert 2018; Ogden 2018; Shiels et al. 2019; Bogardus and Shiels 2020; Table 1). Similar to other traps and rodent control devices, there are many factors that can affect A24 performance and effectiveness, including rat density, alternative food source availability, seasonality, trap density and spacing, lure type and attractiveness, non-target species interference, and rat behavioral requirements to successfully scale and trigger the trap. A salient question often asked by researchers and resource managers considering rat control methods is: Why do A24s work in some cases but not others? This question helped motivate author ABS to organize an Island Invasives symposium and invite A24 trap experts to present at the 29th Vertebrate Pest Conference held in Santa Barbara, California, in 2020, as well as stimulated the production of this special issue of *Management of Biological Invasions*. While this key question of variable A24 effectiveness was not fully answered by our symposium or this special issue, we have made progress and identified future A24 research lines that will support greater confidence in A24 uses and benefits to rodent management. Given the rapid rise in use of A24s as a management tool, our goal was to understand why A24s work in some cases but not others. To address this goal, our objectives were to: 1) introduce a special issue of A24 effectiveness and hazards, and 2) propose future research needs and recommended uses for A24s including a list of potentially susceptible rodent species where further testing is required.

An overview of the special issue

This issue of *Management of Biological Invasions* brings together, for the first time, a collection of case studies that document the uses, effectiveness, and hazards of A24 self-resetting traps. A24 use is rising rapidly for invasive rat control and management, particularly in island natural areas, but their testing and use has focused primarily on just one rat species (*R. rattus* Linnaeus, 1758; Table 1) and in very few types of systems (e.g., never in agriculture until this special issue). Collectively, the studies contained in this special issue begin to address these limitations.

The first study reports on the behaviors of *R. rattus* around A24s when they were deployed over a small (9.3 ha) New Zealand Island with the goal of greatly reducing and ultimately eradicating the rats (Gronwald and Russell 2022). Monitoring rats with motion-activated video cameras at each A24, the authors found that while rats interacted with the traps throughout the year, the number of observed kills was relatively low. The number of rats killed was greatest when rat activity (an indication of relative abundance) was greatest. Although the rat population was reduced by about 80% via continuous trapping with A24s and DOC200 traps, with most of the rat reduction occurring during the first month, rat eradication was never achieved.

A proposed disadvantage to infrequently visiting A24s is that animals killed by A24s may go undetected due to rapid scavenging or decomposition. Counters attached to A24s (Figure 1) only record the number of times the A24 has fired, not the species impacted, and some studies have found A24 counters unreliable (Ogden 2018). Kreuser et al. (2022) addressed the concern of undetected A24 kills by assessing the persistence of bird and rat carcasses over a 4-month period within two large A24 trapping grids (135 ha with 274 traps total) on Kauai, Hawaii, to determine whether managers were: 1) underestimating target (rat) mortality with carcass counts, and 2) failing to detect non-target mortality between periods of A24 trap checks. One trapping grid was located within an ungulate exclusion fence, and the other remained accessible to ungulates. Bird and rat carcasses did not differ in their persistence in the field. The unfenced site had more carcasses removed or becoming undetectable (43%) relative to the fenced site (12% removed or undetectable). The notable difference in scavenging between fenced and unfenced sites was likely due to the high incidence of feral pigs (*Sus scrofa* Linnaeus, 1758) removing carcasses at the unfenced site. Therefore, the current 4-month trap checks can be continued with confidence in the fenced sites, and more frequent trap checks may be considered in unfenced sites to improve confidence in detecting animals killed by A24s.

Following reports of native birds getting killed (Gillies et al. 2014) or injured (Williams 2018) by A24s, Goodnature designed a bird excluder attachment. Two of our papers in this special issue covered the effectiveness and limitations of placing two types of bird excluders onto A24s. In the first study, Crampton et al. (2022) field-tested several A24 modifications that might deter birds but not rat entry, including lure type, lure flavor, excluders, and trap height, to determine if the trap modifications resulted in a decrease in the frequency of rats being killed by A24s relative to A24s without excluders attached and baited with Goodnature chocolate lure. Attaching a 16 cm long metal excluder to the A24 resulted in approximately a 4-fold reduction in rats killed per trap night relative to A24s without excluders attached. In addition, all tested lures except cinnamon, trap heights of 12 cm and 50 cm, and adding the Goodnature plastic excluder (11 cm in length) did not significantly affect rat mortality. However, the question remained: Which types of bird excluders best deter birds from accessing A24s? To address this remaining question, Shiels et al. (2022a) conducted aviary trials using the plastic and metal mesh excluders with red-winged blackbirds (*Agelaius phoeniceus* Linnaeus, 1766), European starlings (*Sturnus vulgaris* Linnaeus, 1758), and a single puaiohi. The first trials were to inform future bird excluder designs by establishing the minimum gap-height beneath a barrier that blackbirds and starlings successfully overcome. The second trials were with disarmed A24s placed at low and high heights and tested with and without excluders attached to A24s. During A24 trials, all three passerine bird species entered the A24s at low or high heights with no excluder and therefore would be at risk of injury. Excluders greatly decreased bird entry into A24s for blackbirds and puaiohi, yet starlings entered traps with and without excluders equally. Based on aviary trials (Shiels et al. 2022a) and field trials (Crampton et al. 2022), the plastic excluder tended to perform best for excluding birds if the bottom of the excluder was positioned 0–2 cm above ground. However, plastic and metal excluders can clog with dead rodents when positioned low. Future trials aiming to exclude all small birds from A24s while maintaining trap efficacy against target rodents should consider new excluder designs as described in Shiels et al. (2022a) and incorporate the 1.9–2.9 cm gap-height thresholds determined in their study.

Because A24s were developed for invasive rat and stoat control, A24s had not been formally tested against house mice (*M. musculus*). There were initial concerns that the small body sizes of mice would result in many injuries or misses if mice triggered A24s. In cage and pen trials, Shiels et al. (2022b) tested efficacy of A24s against wild *M. musculus* to determine whether the time from A24 impact to death was short and met international animal welfare standards (New Zealand National Animal Welfare Advisory Committee [NAWAC]), and whether A24s performed better that snap-traps under simulated field conditions with up to five wild mice present. The A24s passed NAWAC standards of Class B for kill-traps against *M. musculus* as just three out of 67 mice that triggered A24s required intervention and euthanasia because they were injured by being struck by the A24 and still alive after 2 minutes, and that time to death averaged 50.9 seconds (n = 64). Mice triggered A24s baited with peanut butter 2.3 times faster than Goodnature chocolate lure and 2.7 times faster if A24s were angled (45 degrees) in trap stands rather than positioned vertically. When snap-traps were reset each 24 hours within a 24 m^2 arena that simulated field conditions, they killed significantly more mice than A24s, yet if snap-traps were not reset during trials the A24s killed significantly more mice than snap-traps. Overall, A24s appear adequate for use against *M. musculus*, especially if baited with peanut butter and angled in trap stands.

The final paper in the special issue by Baldwin et al. (2022) reports findings from field trials in California citrus orchards where efficacy of rat (*R. rattus*) control by A24s vs. toxic baits (0.005% diphacinone-treated oats) were compared. To our knowledge, this is the first scientific study of A24 effectiveness in an agricultural setting. Bait stations and A24 stations were each arranged in their respective replicate plots in approximately 5 × 5 grids with 76 m between each station, which was based on the mean radius of female rat home ranges in nearby citrus orchards. Surprisingly, neither toxicant nor A24 significantly reduced rats relative to untreated reference plots. There were several strategies identified from this study that hold promise for future testing, including reducing spacing between stations, increasing plot sizes and treatment buffer zones to better reduce rats in the core area of the plots, and use of a platform under the elevated A24s to allow easier access for rats to trigger the traps. These strategies are currently being implemented in a new field study in California citrus orchards.

Future uses, research needs, and recommendations

The use of A24s appears to be increasing worldwide (B. Calder *pers. comm.*, Automatic Trap Company, unpubl. data), peaking interest of land managers and rodent researchers to better understand the range of rodent species that may be effectively controlled using A24s (see Table 2 for rodent species that have interacted with A24s). The species that can be killed by visiting and triggering A24s range in body size from small (mice) to large (ground and tree squirrels) and include many native pest species. Goodnature designed A24s for use against non-native rats and stoats in New Zealand, as there are no native rodents (or land mammals) in New Zealand or on most islands where A24s are currently used. Because non-target species have been killed by A24s, further testing, including humaneness killing trials and field trials, are needed before widespread A24 deployment against these other species can be approved for management. Similarly, additional lab and field studies on *R. norvegicus* Berkenhout, 1769 and *R. exulans* Peale, 1848 (Table 1) would be helpful.

Previous reporting on A24 uses (Table 1), and those presented here, build the body of evidence demonstrating that A24s can be used successfully to control rodent populations of some species in particular environments.

Table 2. Sizes of rodent species assessed (directly or indirectly) for susceptibility to Goodnature A24 self-resetting rat+stoat traps (A24s). Effectiveness in this context reflects the A24's ability to attract and kill individuals of each species. When rodent body sizes were unavailable for the associated study (e.g., several field studies), a reference that includes body size data from a nearby location is provided. An asterisk denotes a study that is part of this special issue of *Management of Biological Invasions*.

Rodent species	Size range (g)	Lab or field assessments? (country)	A24 effective?	Citation
House mouse (*Mus musculus*)	16–30	Lab (USA), Field (NZ & USA & Canada)	Yes	*Shiels et al. (2022b); Gillies et al. (2014); Coad et al. (2017); Ryan (2021)
Western harvest mouse (*Reithrodontomys megalotis*, Baird, 1857)	9–14 (adult sizes based on Jameson and Peeters 2004)	Field (USA)	Yes	Gilliland (2020)
Wood mouse (*Apodemus sylvaticus* Linnaeus, 1758)	16–39	Lab (UK)	Yes	R. van Dam *pers. comm*., by providing report "Goodnature A24 trap for control of mice – Pen trials"
Deer mouse (*Peromyscus maniculatus* Wagner, 1845)	14–25 (adult sizes based on Jameson and Peeters 2004)	Field (USA & Canada)	Yes	Gilliland (2020); Ryan (2021)
Field vole (*Microtus townsendii*, Bachman, 1839)	75–82 (adult sizes based on Jameson and Peeters 2004)	Field (Canada)	No, voles only visited the outside of the traps	S. Hindmarch *unpublished data*
California ground squirrel (*Otospermophilus beecheyi* Richardson, 1829)	353–485	Field (USA)	Yes	Gilliland (2020)
Fox (tree) squirrel (*Sciurus niger* Linnaeus, 1758)	380–527	Field (USA)	Yes, but likely for smaller individuals only	S. Shiels *unpublished data*
Gray (tree) squirrel (*Sciurus carolinensis* Gmelin, 1788)	500–625 (adult sizes based on Jameson and Peeters 2004)	Field (Canada)	Yes for juveniles, no for adults, as only a juvenile was killed & two adults were injured	Ryan (2021)
Black-tailed prairie dog (*Cynomys ludovicianus* Ord, 1815)	860–1200	Lab (USA; measurements only)	No, not likely, as adult neck girth is too large to fit in trap entrance and access trigger	A.B. Shiels *unpublished data*

Frustration remains with our inability to determine why A24s are inconsistent in their effectiveness at reducing rodent populations in all instances, including habitats and time periods. Some of this frustration goes beyond A24s, as it is a pattern in wildlife damage management and population control that occurs with many species and most control devices. For example, in addition to the ineffectiveness of A24s at reducing rat populations reported in Baldwin et al. (2022), rat populations were not consistently reduced in plots with toxic baits offered, and such baits are typically highly desired by rats (e.g., Baldwin et al. 2014; Gilbert 2018). Additional examples from this special issue of experiences with A24s that did not meet our expectations include: 1) thirteen house mice in Shiels et al. (2022b) never triggered an A24 even when food was withheld from within small (60 × 60 × 60 cm) cages, 2) later in Shiels et al. (2022b) when groups of five mice were placed in a 24 m^2 arena, the average time for a mouse to trigger an A24 was 42 hours, and 3) the majority of the rats recorded near A24s were not attracted to A24s but consistently traveled past it in Gronwald and Russell (2022). Contrasting evidence from our special issue where A24s were effective included: 1) the first month of use against rats on a New Zealand offshore island (Gronwald and Russell 2022), and 2) the long-term suppression of the rat population on Kauai relative to years prior when no rat control was practiced (Crampton et al. 2022). These frustrations and inconsistencies with A24 effectiveness motivate further research questions aimed at determining solutions and providing a clear answer to the question posed earlier: Why do A24s work in some cases but not others?

Like most answers to ecological questions, our best attempt at answering the above question about the inconsistent effectiveness of A24s is that it depends (on potentially multiple, interacting factors). We believe some of the key factors that affect A24 performance and effectiveness include: rat density, abundance and type of alternative food sources, seasonality, trap density and spacing, lure type and attractiveness, trap access, mechanical failures, and non-target interference. Additional research into each of these factors is needed, and such research planning requires the realization that different rodent species and habitats may have large impacts on A24 effectiveness studies. To assist resource managers in better choosing the most effective and cost-efficient control methods to use, including integrative pest management approaches, studies with the specific objective to compare performance of A24s with other rodent control techniques (e.g., other traps, approved rodent toxicants; Gilbert 2018; Baldwin et al. 2022) would be highly beneficial. Additionally, rarely is it known how low rodent densities need to be before noticeable gains are achieved in the resources that trapping is used to benefit, and such thresholds will almost certainly vary depending on local environmental factors and the type of resource (e.g., species, infrastructure) that one is trying to protect from rodent damage. For example, a rat population needed to be reduced to < 10% activity in tracking tunnels to benefit one sensitive bird species in New Zealand (Innes et al. 1995), whereas in Hawaii it needed to be reduced to ≤ 20% activity in tracking tunnels to protect an endangered plant from significant rat frugivory and predation of the seeds (Pender et al. 2013).

Based on our experiences with A24s, the findings in the literature, and the papers in this issue, we have the following operational recommendations (separated by rat and mouse) that build upon those made in Bogardus and Shiels (2020).

Recommendations and expectations for A24 uses against rats

- Rat density and environment: the more that is known about a management site's rodent ecology, including rat density, the better. Modeling has suggested that multi-catch traps are most effective at sites where target vertebrate densities are high, and at low density sites single-catch traps (e.g., snap-traps) are recommended (Warburton and Gormley 2015). We further recommend that this density-dependence hypothesis be field tested with A24s and snap-traps.
    - Where rat densities are high, such as when a site is first managed for rats, expect A24s to work better at reducing the population than when rat densities are low (as demonstrated in Gronwald and Russell 2022 and described in Crampton et al. 2022).

  - Once rats have been suppressed for many months with A24s, expect there to be seasonal increases in rat densities that correspond to periods of favored food items or other seasonal changes, where A24s do not appear to adequately maintain low rat densities. Supplementing A24s with additional rat management techniques (e.g., rat barriers protecting resources, toxic baits) may be considered at such times (as described in Shiels et al. 2019).
- Trap density and spacing: these factors will again depend upon site conditions. A24 grid spacing of 50 × 100 m was trialed with success in New Zealand (Carter and Peters 2016; Carter et al. 2016). A24 grids with 76 m spacing did not reduce rats in citrus orchards (Baldwin et al. 2022). Tighter spacing (e.g., 25 m apart), and therefore more traps, may be needed to reduce rat populations and damage to desired levels (Gilbert 2018; Bogardus and Shiels 2020). Avoid placing a single trap, or very few traps, in an area to obtain reductions in the local rodent population and damage.
- Lure type, attractiveness, and longevity: Given that A24s are highly effective at killing rats when trap triggering occurs, the attractiveness of the lure in drawing rats into the trap seems like the key factor needing improvement when A24s are not reducing rat populations to desired levels.
  - Use peanut butter-based lure or chocolate lure for ensuring the best palatability (Crampton et al. 2022), and 5% citric acid integrated into the bait can extend bait longevity in areas of high slug interference (Bogardus et al. 2020; Shiels et al. *unpublished data*).
  - Automatic lure pumps (ALPs) are recommended for use in areas where traps are not planned to be frequently serviced (Bogardus and Shiels 2020). However, Crampton et al. (2022) found no evidence of differential attractiveness of static lures vs. ALPs, and Ogden (2018) found > 50% of ALPs failed, so we recommend that all new projects using A24s with either static lures or ALPs check traps and lures more frequently (e.g., weekly) at the beginning of their project to ensure proper lure condition (and ALPs functionality).
- Trap access: Position traps near the ground or elevated to 50 cm height (Crampton et al. 2022; but see non-target section below). If elevated (e.g., to avoid interference with feral pigs or other ground-dwelling non-target species), consider including a platform just below the A24 entrance to facilitate trap access for target rodents (Baldwin et al. 2022). See Shiels et al. (2022a) for bird excluder designs when using a platform below an elevated A24.
  - Mechanical failures: A24 trap lifespan should be considered when planning for long-term use. Goodnature currently provides a 2-year warranty on each trap and they state that most traps fail at varying

times between year 3 and 10. Most failures are gas leaks (T. Bogardus *unpublished data*). Additionally, ALPs can fail at variable rates (e.g., no failures to > 50% of ALPs used; Ogden 2018).

- Non-target interference: A24s were designed to reduce access to some non-target species (e.g., large birds and mammals). For this reason, A24s should exclude greater incidences of non-target triggerings than uncovered snap-traps.
  - Excluders are not recommended to attach to A24s unless rare or sensitive non-target species are likely to frequently visit and explore the inside of A24s (Shiels et al. 2022a). Evidence presented in Crampton et al. (2022) demonstrates that attaching excluders to A24s does not facilitate rat entry, yet instead, some excluders significantly reduce the frequency of rats killed by A24s.
  - If carcasses are used to gauge whether target and non-target kills occurred by A24s, there should be some prior knowledge of the scavenging community and frequency. Feral pigs removed and consumed bird and rat carcasses near A24s in Kreuser et al. (2022) and the unfenced sites had far more scavengers than fenced sites. To best estimate A24 kills, field staff may need to adjust their visitation frequencies to A24s based on scavenging frequencies.
  - If excluders are required to reduce or eliminate birds from entering A24s, the Goodnature plastic excluder tended to perform best for preventing A24 entry of passerines if the base of the excluder was positioned 0–2 cm above ground. However, if 100% protection from A24 injury and death is desired for birds, additional testing appears necessary, and this may require a new excluder design with a wider diameter, as well as a gap-height threshold appropriately sized for the sensitive bird species in the A24 deployment area (Shiels et al. 2022a).

Recommendations and expectations for A24 uses against mice (following Shiels et al. 2022b)

- For A24 use against *M. musculus*, baiting with peanut butter and angling the A24s in trap stands should enhance A24 efficacy. Additionally, Goodnature trap stands allow armed A24s to be easily and safely moved and placed to capitalize on areas of high mouse activity and sign.
- Use A24s when planning to visit traps infrequently. If personnel are planning to visit traps daily, or nearly so, traditional snap-traps should be considered for greater efficacy and lower financial burden than A24s.

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Authors' contribution

ABS conceptualized the A24 special issue and this introductory paper. ABS and CAL analyzed and interpreted data. ABS wrote the original draft. All authors reviewed and edited the manuscript.

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