## Title

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# Do Scent Lures Increase Visitation of Bait Stations by Urban Roof Rats?

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**ABSTRACT:** Roof rats (*Rattus rattus*) are invasive commensal rodents that pose a significant threat to both natural and manmade environments. Like other commensal rodents, roof rats are often controlled with rodenticides placed within bait stations, but rats can be slow to visit stations or avoid them altogether. We tested whether the addition of a scent lure (Airzonix; VM Products) would increase visitation and use of bait stations in 36 residential yards in Orange County, California. We placed two EZ-Secured (VM Products) stations, one containing a scent lure and non-toxic bait (treatment) and one containing bait only (control), in each yard, and monitored them continuously with digital game cameras for three weeks. We compared time to discovery and entry, bait consumption, and nightly roof rat activity between scent lure and control stations. The addition of a scent lure did not reduce time to discovery or entry significantly, nor did it increase bait consumption or rat activity, although rat behavior differed around scent lure and control bait stations. Overall, although roof rats discovered bait stations fairly quickly (median time to discovery 124-195 h), they entered and consumed bait in only a fraction (50-60%) of the stations, and were slow to enter stations (median time to entry 318-387 h), underscoring that additional techniques are still needed to improve the attractiveness and efficacy of bait stations.

**KEY WORDS:** California, commensal rodents, pest management, Rattus, rodent activity, rodent behavior, rodenticide bait stations, scent lure

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## INTRODUCTION

Commensal rats and mice (*Rattus rattus*, *R. norvegicus*, *Mus musculus*) inhabit most continents and a large majority of global islands, where they have devastating effects on the human and natural world (Pimentel et al. 2000). As successful omnivores and predators, these invasive rodents pose a great threat to species of conservation risk (Witmer et al. 1998, Pimentel et al. 2000, Banks and Hughes 2012). It has been estimated that almost half of global islands which harbor highly threatened species are also home to at least one invasive *Rattus* species (Spatz et al. 2017). In commensal environments, where rats maintain close contact with humans, they have been known to transmit diseases, such as typhus, plague, and leptospirosis, to both humans and native wildlife (Lapuz et al. 2008, Meerburg et al. 2009, Himsworth et al. 2013). Despite these effects, successful management of rats remains challenging. For example, despite improvements in factors, such as sanitation, that are associated with rat infestations, in Baltimore, Maryland, the residential Norway rat (*R. norvegicus*) population has remained relatively stable, if not increased, since the mid-20th century, indicating that our current understanding and subsequent management of these invasive rodents needs improvement (Easterbrook et al. 2005, Parsons et al. 2017).

People have attempted to control rodents for centuries, and most home- and landowners in California rely on snap-traps, glue boards, and rodenticides placed in bait stations to manage local rodent problems (Morzillo and Mertig 2011). Historically, people have attempted biological control methods, such as the introduction of cats or dogs, to control rodents, but there is little evidence that these animals can consistently manage invasive rats (Krijger et al. 2020, Esther et al. 2022) and may themselves cause significant harm (Medina and Nogales 2008, Doherty et al. 2016). Since the mid-20th century, anticoagulant rodenticides have been widely used; however, these compounds pose serious risks to children, non-target wildlife, livestock, and pets that are exposed to the rodenticide directly or to dead or dying rodents (Ruiz-Suarez et al. 2014, Nakayama et al. 2017). To minimize non-target exposure, rodenticides usually must be placed within bait stations, but recent research suggests that commensal roof rats do not enter many of the bait stations that they encounter, suggesting neophobia, and the behavior of rats around bait stations remains poorly understood (Quy et al. 1994, Burke et al. 2021, Frye et al. 2021).

Some researchers have used chemical scent attractants to increase the likelihood of rats interacting with traps (Takács et al. 2016b, Takács et al. 2018). Jackson et al. (2018a) found that invasive wild rats in New Zealand were significantly more attracted to tracking tunnels and chew cards containing synthetic attractants (e.g., 1-hexanol, isobutyl acetate, acetoin) than to those baited with peanut butter (Jackson et al. 2018a). In our study, we hypothesized that a food-imitating scent lure placed within a rodenticide bait station would increase the likelihood of commensal roof rats visiting the station. Specifically, we tested whether the addition of a scent lure inside a widely-used commercial bait station would influence the time to discovery and entry by rats, bait consumption, and nightly rat activity around the bait station.

## METHODS

### Experimental Design

We placed a pair of EZ-Secured bait stations (VM Products, Bedford, TX, USA) in each of 36 residential yards ('sites') in Orange County, CA during trials conducted in June and July 2023. All homeowners permitted access to their yards for the duration of the experiment. Each station contained four non-toxic Rat and Mouse Attractant bait packs (LiphaTech, Milwaukee, WI; no active ingredient). In the treated station, we included an Airzonix scent lure (VM Products; "Peanut Butter/ Chocolate" scent), with the scent lure fitted into a hair-roller, wrapped in steel wool, and fastened to the back wall of the feeding chamber to prevent the lure's removal. The lure is not food-based and contains a proprietary blend of ester compounds to mimic the scent of peanut butter and chocolate. When installed within the station, the scent was still easily noticeable to the human observer, and the odor was maintained throughout the three-week observation period (verified during our weekly visits to each site). The other bait station had no scent lure and was considered a control.

Bait stations were placed in locations with visible rat activity (droppings, gnaw/rub marks). If there were no indications of rat activity, stations were placed haphazardly near physical structures or along bordering walls. All stations were placed within 1 m of some type of vegetation or potential harborage and not out in the open. At the start of the experiment, we met with the homeowners and recorded the characteristics of each yard, such as presence of pets and livestock, fruits and vegetables, evidence of rat activity, and the homeowner's characterization of current and past rodent management (Table 1). The distance between stations in a given yard necessarily varied depending on the yard's size, which ranged from <100 $m^2$ to >4000$m^2$, but stations were placed far enough part (>10 m) within each yard that we considered them independent. Each station was monitored by a game camera (Reconyx HF2X Hyperfire 2 Trail Camera; Reconyx, Holmen, WI, USA), which captured three images in sequence upon motion detection, with 1 s between images. Stations were monitored for three weeks (21 nights). Each week, we visited the stations to replenish the bait, check the scent lures, and change batteries and data storage cards.

For each station, we estimated bait consumption weekly by visually checking the bait in the station. We used camera images to estimate the time to discovery and the time to entry. Time to discovery was elapsed time, in hours, between sunset on the first night the station was in place to the first camera image showing a roof rat showing 'interest' (placing a forelimb on the station, inserting their head into station entrance) in the station. Time to entry was the elapsed time, in hours, between sunset on the first night and the first image showing a roof rat entering the station. Bait consumption was estimated visually each week as the percentage consumed. For a given station, percent bait consumption was averaged across weeks and then scored on an ordinal scale: 0 = 0 - 5.0% bait consumed, 1 = 5.1 - 33.0% consumed, 2 = 33.1-66.0% consumed, 3 = 66.1 - 100% consumed. Relative rat activity was calculated per night at each station as the proportion of nightly hours with at least one image of a rat at the station. For each site, we then calculated the mean proportion of hours of rat activity per night for each station during the first week, when the stations were new to the environment, and then across all 21 nights.

### Data Analysis

To compare times to discovery and entry by roof rats between scent lure and control stations, we used a log-rank Mantel Cox test with mixed effects in R (version 2.2-20; package 'coxme'). For both analyses, the response variable was time to discovery or entry, the fixed effect was 'station treatment' (scent lure or control), and the random effect was 'site.' Sites where no roof rats were detected (N = 9) were omitted from the analysis. To compare bait consumption within each of the station treatment, we used a cumulative link mixed-model (R version 2023.12-4; package 'ordinal') with 'station treatment' as the fixed effect, 'site' as a random effect, and bait consumption category (0, 1, 2, 3) as the response variable. We also analyzed the effect of station treatment on mean nightly activity for the first week only, and for the entire duration of the experiment. For both of these analyses, the effect of station treatment on mean nightly activity was compared using a linear mixed-model, with 'site' as a random effect and 'station treatment' as a fixed effect (R version 3.1-3; package 'lmerTest'). Figures were created using 'survminer' (version 0.4.9) and 'ggplot2' (version 3.5.0) packages in R.

## RESULTS

Most bait stations in the 27 yards with roof rats were discovered by the end of the three-week experiment (control = 81%, scent lure = 89%). However, only 50-60% of the stations were actually entered by the end of the experiment (Table 2). There was no significant difference between control or scent lure stations in terms of time to discovery ($\beta_{scent} = 0.06 \pm 0.32$, $p = 0.86$) or entry ($\beta_{scent} = 0.47 \pm 0.41$, $p = 0.25$), although the scent lure seemed to have a stronger effect on entry versus discovery (Figures 1 and 2). Median time to discovery was roughly three days (71 hours) later for scent lure station, but median time to entry was almost three days (69 hours) earlier, suggesting the scent lure might have lowered the latency to entry (Table 2).

**Table 1. Characteristics of 36 residential yards in Orange County, California, used for an experiment in summer 2023 to determine if scent lures increase roof rat visitation to bait stations. Landscaping intensity was categorized from a value of 1 for highly manicured lawns to a value of 3 for yards with dense or overgrown vegetation.**

| Characteristics | Number of yards | % of yards |
|---|---|---|
| Fruits and/or vegetables | 32 | 89 |
| Pets and/or livestock | 31 | 86 |
| Landscaping intensity | | |
| 1 | 20 | 56 |
| 2 | 12 | 33 |
| 3 | 4 | 11 |
| Evidence of rat activity | 26 | 72 |
| Previous rat management | 18 | 50 |

Table 2. **Median times to discovery (discovery defined as the first instance in which a roof rat shows 'interest' in station, i.e., placing forelimb on station or sticking its head into the station entrance) and entry for each bait station treatment (control, scent lure), along with the total number of stations and percentage that were discovered or entered in residential yards in Orange County, California, in summer 2023.**

| Variable / Treatment | Hours (range) | Number of stations (% of yards) |
|---|---|---|
| Time to discovery | | |
| Control | 124 (1-486) | 22 (81%) |
| Scent lure | 195 (0-482) | 24 (89%) |
| Time to entry | | |
| Control | 387 (2-387) | 14 (52%) |
| Scent lure | 318 (0-483) | 17 (63%) |

There was no significant difference in the amount of bait consumed between scent lure and control stations ($\beta_{scent} = 1.05$, $p = 0.113$), although stations with scent lures tended to have greater bait consumption than control stations throughout the experiment (Figure 3). All stations where we detected entry using cameras had evidence of bait consumption, and no bait consumption by rats was detected in stations in which we had no images of entry (although we did occasionally photograph non-target rodents entering stations, such as *Peromyscus* spp., *Neotoma* spp., and *Mus musculus*). Mean nightly activity was lower at stations with scent lures than at controls during the first week of our experiment, but this difference was not significant ($t = -0.31$, $p = 0.76$). Across all three weeks, mean nightly activity was higher at scent lure stations than at control stations, although the difference was not significant ($t = 1.24$, $p = 0.227$).

## DISCUSSION

The use of a scent lure to attract target species to areas of interest is not a novel idea, but most research on this topic involves predators, such as canids and mustelids (Randler et al. 2020, Cozzi et al. 2022). Recent research suggests that scent lures can significantly increase detection rate of predators at camera traps in Canadian forests, but not detection rates of prey species, such as small mammals (Holinda et al. 2020). There is limited research on the effectiveness of scent lures as attractants for rats. In captivity, Norway rats seem to be attracted to some scents (almond, lemon, ginger) over others, but this attraction does not lead to increased capture success when those same scents are used to trap Norway rats in the field (Witmer et al. 2008). This suggests that the addition of a scent lure may be insufficient to entice rats to interact with unfamiliar management devices. Takács et al. (2018) found that a mix of a variety of synthetic food scents imitating hazelnut, chocolate, coconuts, and candy did not increase the likelihood of catching rats in snap-traps, but incorporating these compounds into a bait formulation along with salmon and safflower oil increased the capture rates of

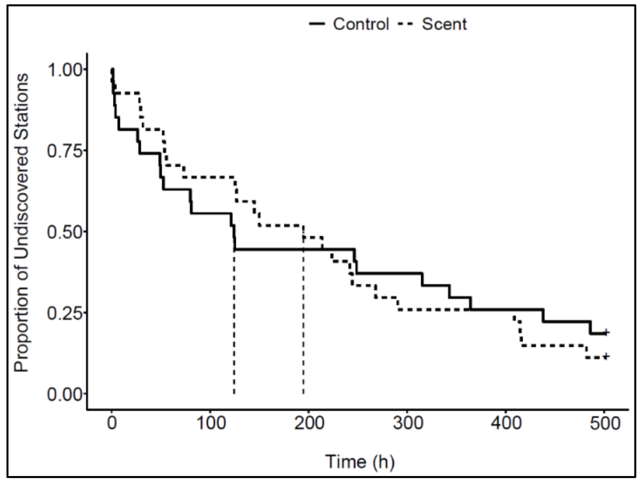


**Figure 1. Survival curves showing time to discovery for control (solid line) and scent-lure (dotted line) stations in yards where roof rats were detected (N = 27) in Orange County, California, in summer 2023. Median time to discovery (control 124 h; scent lure 195 h) is shown by the vertical dashed lines.**

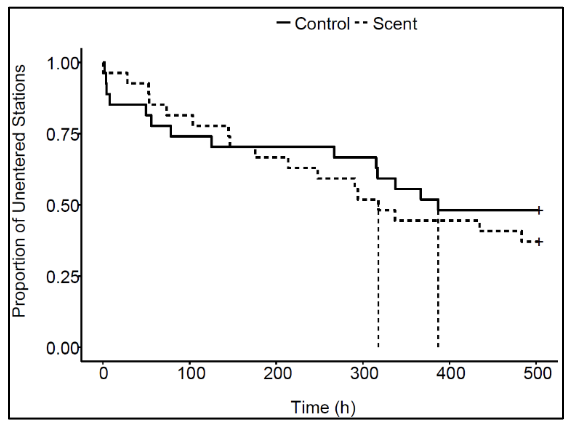


**Figure 2. Survival curves showing time to entry for control (solid line) and scent-lure (dotted line) stations in yards where roof rats were detected (N = 27) in Orange County, California, in summer 2023. Median time to entry (control 387 h; scent lure 318 h) is shown by the vertical dashed lines.**

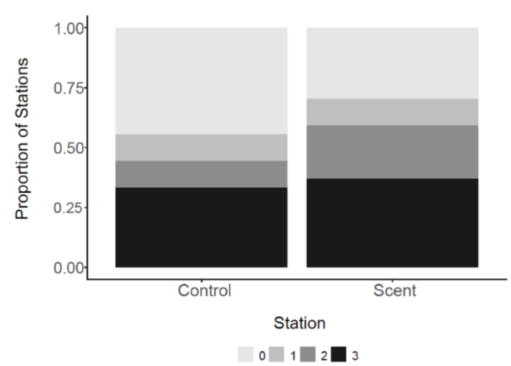


**Figure 3. Proportion of control and scent lure stations in each bait consumption category (0-3) across sites where roof rats were detected during the experiment in residential yards in Orange County, California, in summer 2023.**

Norway rats, roof rats, and house mice. Thus, it is possible that combining multiple different food scents into a bait could increase the attractiveness of a device. Conversely, Jackson et al. (2018b) found that a combination of scents mixed into one formulation was no more effective at attracting rats than single-compound lures. The synthetic lure we used was formulated from artificial ester compounds to mimic a peanut butter and chocolate odor, but it differed from the bait we used, which might explain why our lure did not prove particularly attractive to rats in the yards we studied. We also note that the scent of the lure we used was initially very intense, at least to the human observer, although the strength of the odor seemed to dissipate over time. Jackson et al. (2018a) found an inverse relationship between scent lure attractiveness and the concentration of the odor; therefore, it is possible the strength of the lure scent may have acted as a deterrent rather than attractant, at least for the initial part of the experiment. This might explain the reduced nightly activity at the scent lure stations during the first week of our experiment.

One concern about using lures with the scent of potential foods is that rats may not be attracted to them if sufficient natural food resources are plentiful (Linklater et al. 2023). Many of the yards we studied (and their neighbors) had fruits, vegetables and other food sources that were in season during our summer sampling, which might have been more attractive than the synthetic lure. Of course, bait competition with natural foods is a problem for baited traps and stations as well, which might partly explain the relatively low entry rates (50-60%) we encountered.

Lures with scents other than food aromas might be more successful for attracting wild roof rats to traps or bait stations. Takács et al. (2016b) found that Norway rats regularly visited traps or bait containing odors of other rats, such as soiled bedding, urine, and feces, or, interestingly, playbacks of ultra-sonic vocalizations of rat pups. In a lab study, female roof rats consumed significantly more poison bait when it was treated with gland extracts and urine from male roof rats (Selvaraj and Archunan 2006). Shapira et al. (2013) found that placing live laboratory rats in cages near live traps significantly increased field capture rates of Norway rats in a New Zealand scrubland. Thus, it seems that rats may be likely to interact with management devices containing familiar and/or conspecific scents, rather than odors associated with foods. To our knowledge, there have not been any studies using conspecific odors to attract wild roof rats to traps, bait stations, or tracking devices, but this could be explored as a possible alternative.

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