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Authors
Baldwin, Roger A.
Smith, Justine A.
Meinerz, Ryan
et al.

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Managing Roof Rats in Citrus Orchards: Initial Efforts toward Building an Integrated Pest Management Program

Roger A. Baldwin, **Justine A. Smith**, and **Ryan Meinerz**
Department of Wildlife, Fish, and Conservation Biology, University of California-Davis, Davis, California
Aaron B. Shiels
USDA APHIS, Wildlife Services, National Wildlife Research Center, Fort Collins, Colorado

ABSTRACT: Roof rats cause extensive damage in orchards throughout the world. Integrated Pest Management (IPM) systems are the best option for managing rodents, yet few management systems have been developed and tested to control roof rats in agricultural settings. We initiated a study in 2020 to provide the foundation for an IPM program to manage roof rats in California citrus orchards. Our initial efforts centered on developing effective monitoring strategies for roof rats to determine when management actions are needed, assessing rat movement patterns to determine proper placement of management tools, and conducting initial tests of Goodnature A24 self-resetting traps and elevated bait stations containing 0.005% diphacinone-treated oats. We determined that the use of both tracking tunnels and remote-triggered cameras served as effective monitoring tools for roof rats in citrus orchards, and a smaller 3 × 3 grid placement of these monitoring tools was as effective as a 5 × 5 grid, indicating that substantial material and labor costs could be saved by using the smaller grid size. Placement of the monitoring tools on the ground or up in trees did not influence the effectiveness of this approach. We determined that roof rats exclusively used orchard habitats rather than surrounding fields, so control efforts should be focused in these areas. Roof rats moved substantial distances daily (~170-190 m), but results from bait station trials suggest that spacing of bait stations and traps should be closer together to increase roof rat encounter rates of these devices. Our trial with A24 traps elevated in orchard canopies suggest that there is an advantage to including a platform underneath the trap to increase trap activation. Collectively, this information provides a baseline for future research targeted at developing an effective IPM program for managing roof rats in citrus orchards.

KEY WORDS: bait station, citrus, diphacinone, Goodnature A24 trap, home range, integrated pest management, population index, *Rattus rattus*, roof rat

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INTRODUCTION

Integrated pest management (IPM) is widely considered the most effective strategy for managing pests in agricultural settings (Engeman and Witmer 2000, Sterner 2008), yet efforts to develop IPM programs for field rodents are often lacking. Roof rats (*Rattus rattus*) are a common agricultural pest globally. They cause substantial damage in tree crops including consumption of fruits and nuts, girdling of branches, and damage to irrigation infrastructure, and they can pose a food safety risk through fecal contamination of fruits and nuts (Worth 1950, Yabe 1998, Baldwin 2016). This is particularly true for citrus crops, where abundant food and cover is generally available throughout the year. Traditional management efforts to reduce rat damage in tree crops have often focused on anticoagulant rodenticides applied via bait stations. This approach has proven effective in some crops (Baldwin et al. 2014), but exclusive use of a single tool such as anticoagulant rodenticides often leads to a reduction in efficacy over time and could in fact lead to anticoagulant resistance in target populations (Salmon and Lawrence 2006). Furthermore, there is increasing interest in reducing reliance on anticoagulant rodenticides, prompting the need for alternative strategies to combine with rodenticides to maximize efficacy, reduce treatment costs, and minimize potential environmental effects (Baldwin and Salmon 2011).

Few alternative strategies are practical for use in citrus orchards. Habitat modification isn't applicable given that the trees provide abundant shelter year-round, chemical repellents have not proven effective for roof rats, and exclusion is not possible in an orchard setting. As such, trapping is one of the few remaining options that could be used. That said, traditional snap trapping is time consuming given the need to check traps to rebait and reset following capture. An alternative method is the use of automatic resetting traps, such as the Goodnature A24 trap (Goodnature Ltd., Wellington, NZ). A24 traps have been used extensively in island conservation settings over the last decade, and they have proven effective at reducing rat numbers in many of these areas (Carter et al. 2016, Shiels et al. 2019, Gronwald and Russell 2022). These traps contain a long-lasting lure and will reset up to 24 times per CO_2 cartridge when activated, providing the potential for a "place and forget about" option for 4-6 months at a time. Such a strategy could be highly desirable for citrus growers, but their efficacy has yet to be tested in an agricultural setting where food resources are often abundant.

Regardless of whether or not bait stations or traps are used, a good understanding of areas that rats use, as well as rat movement patterns, would greatly increase the effectiveness of each management strategy (Ramsey and Wilson 2000, Whisson et al. 2007). For example, do roof rats primarily use orchard habitats, or do they utilize both orchards and adjacent habitats? If the latter, then treatment applications could be targeted outside of orchards if deemed beneficial. Also, knowing how far roof rats travel would assist in determining proper spacing between bait stations or traps. Such information is lacking in orchard settings in California.

One item often overlooked in IPM programs is effective monitoring of pest populations (Sterner 2008). A number of strategies can be employed for small rodents, but the appropriateness of a given strategy can vary depending on the ecology of the system monitored (Engeman and Whisson 2006). Tracking tunnels and remote-triggered cameras have been used effectively to monitor changes in roof rat activity in a variety of settings (Brown et al. 1996, Baldwin et al. 2014, Shiels et al. 2019), and both could prove to be viable options in citrus orchards in California as well. If proven effective, these monitoring strategies could be used by researchers to determine the effectiveness of various management strategies, and they would allow growers to determine when management actions are needed in their fields to reduce roof rat numbers. As such, we established several studies in citrus orchards to begin to address these topics. Specifically, we established the following objectives: 1) determine the effectiveness of tracking tunnels and remote-triggered cameras at indexing roof rat activity, 2) assess habitat use and movement patterns of roof rats in citrus orchards, and 3) determine relative effectiveness of A24 traps and a 0.005% diphacinone grain bait applied via bait stations at reducing roof rat numbers in citrus orchards. In this paper, we provide brief highlights from these studies. Greater detail can be found in referenced papers already published.

METHODS

Roof Rat Indexing

We established 5 study plots across 3 lemon and 2 orange orchards in the southern San Joaquin Valley for this trial. Within each plot, we established 5 × 5 and 3 × 3 grid structures that contained tracking tunnels and remote-triggered cameras at each grid point to determine if smaller grid sizes could be equally effective as monitoring approaches. For cameras, we assessed activity via presence-absence, as well as through the development of a general index value (number of roof rat visits per camera station per night; Baldwin et al. 2014). Half of the tracking tunnels and cameras were elevated up in trees, while half were placed at ground level to determine if elevated status influenced the effectiveness of indexing tools. We operated tracking tunnels and cameras for 3 days and then compared those index values to both minimum number known estimates and estimated population size from live trapping efforts on each study plot. All indexing tools and traps were baited with Liphatech Rat and Mouse Attractant

soft baits given the known attractiveness of this bait for roof rats in citrus orchards (Wales et al. 2021).

The number of camera sites and the number of tracking tunnels visited by roof rats accurately reflected both population estimates, and minimum number known estimates of roof rats within citrus orchards. General index values derived from cameras also accurately reflected roof rat numbers within orchards. As such, all 3 of these monitoring approaches could be effectively used to track changes in rat activity over time. This is an important finding given that corroborative tools are required by the United States Environmental Protection Agency when validating the efficacy of pesticides. That said, tracking tunnels are cheaper and easier to operate, and as such are more practical for use by producers and pest control professionals.

We also determined that 3 × 3 grids of cameras and tracking tunnels were equally as effective as 5 × 5 grids, so substantial labor and associated costs could be saved by using the smaller grid size. We did not identify any impact of elevated versus ground placements of indexing tools, so both could be used in monitoring programs. However, we did observe a difference in the relationship between index values and roof rat numbers in lemon versus orange orchards. Reasons for this difference are unknown, but they do illustrate the need to consider different habitat types when using population indices. Collectively, this information will be very useful in allowing researchers, producers, and pest control professionals in tracking changes in roof rat numbers over time. Please see Baldwin and Meinerz (2022) for greater detail on this study.

Roof Rat Movement Patterns

We used Cellular Tracking Technologies PowerTag (CTT PowerTag; Cellular Tracking Technologies, Rio Grande, NJ) to track movement patterns of roof rats in 3 citrus orchards in the southern San Joaquin Valley during winter and summer 2020. For this process, we collared 45 roof rats across the three sites with CTT PowerTags that emitted a unique digital ID signal that was detected by nodes that were placed throughout the orchard. The nodes then sent a signal to a centralized SensorStation that recorded location data collected from all nodes. We then used triangulation to determine roof rat locations every few seconds throughout each site. These rat locations were used to develop 95% adaptive kernel home ranges for each individual to determine mean home range size for both males and females, as well as to overlay onto satellite imagery to determine if roof rats moved out of orchards or spent all their time within orchards. We also filtered movement data to determine the mean maximum distance that a roof rat moved daily to help inform optimal spacing for traps and bait stations.

We collected sufficient roof rat location data for analysis for 2 of our 3 study sites. For our first study site, we transmittered roof rats at the end of February, but all research efforts were shut down shortly thereafter due to the Covid-19 pandemic. This kept us from keeping equipment operational during the Covid lockdown. As such, we obtained limited data from this study site, so we removed these data for analyses. For the other 2 study sites, we obtained substantial data on roof rat movement patterns during summer. We determined that roof rats exclusively used orchard habitats, indicating that control efforts should be centered within orchards. We found that roof rats utilized relatively large areas, with home range diameters around 150-180 m. Transmittered roof rats moved long distances daily, with mean linear distances moved of around 170-190 m per day. We used the mean radius of a female roof rat's home range to suggest spacing of 76 m between bait stations and traps for use in future studies.

Pilot Study: Diphacinone Bait Stations and A24 Traps

We tested the efficacy of 0.005% diphacinone-treated rolled oats (California Department of Food and Agriculture, Sacramento, CA) placed in elevated bait stations, as well as the use of A24 traps elevated in citrus trees across 4 study sites in citrus orchards in the southern San Joaquin Valley during spring through autumn 2021. Bait stations were generally spaced 76 m apart based on movement data highlighted in the previous section, although we reduced spacing to 50 m at one site to determine if shorter spacing might increase efficacy. We operated bait stations for 4 weeks at 3 of 4 sites, but we extended the baiting duration to 6 weeks at one site to see if longer access to bait might increase efficacy.

Spacing for A24 traps was 76 m across all sites. As with bait stations, we operated A24 traps for 4 weeks at 3 of 4 sites, but extended the trapping duration to 6 weeks at one site to see if that might improve efficacy. We placed A24 traps up in trees without a platform underneath for 3 sites, but for one site, we placed platforms ~12 cm below the entrance of the trap to determine if platforms might increase ease of access by rats to the traps, and subsequently increase the efficacy of the traps. Trap attractants varied across sites but included Goodnature Rat and Mouse Chocolate Lure applied via an automatic lure pump, the same chocolate lure applied via the Goodnature Do-It-Yourself Lure Basket, and creamy peanut butter applied in the same lure baskets. We tested for efficacy of both A24 traps and elevated bait stations by comparing index values determined during pre- and post-treatment periods using protocols previously defined for tracking tunnels and remote-triggered cameras.

RESULTS

We did not observe a substantial reduction in roof rat abundance across 2 of 4 study sites, although we did observe >80% efficacy for 2 sites. One of the sites where we observed a substantial reduction in roof rat activity was the site that we reduced the distance between bait stations to 50 m, suggesting that shorter intervals might increase bait uptake by roof rats. Increasing the duration of baiting by 2 weeks did not increase efficacy, as we observe a 20% increase in roof rat activity after the baiting period.

For A24 traps, we observed greater roof rat activity for 3 of 4 sites after the treatment period (>31% increase across the 3 sites), indicating that this approach was not effective. However, for the one site where we placed a platform beneath the trap, we observed a 50% reduction in roof rat activity, suggesting that these platforms may substantially increase the effectiveness of the A24 trap in citrus orchards. Increasing the trapping duration by 2 weeks had no effect on our trapping program, nor did we observe any noticeable benefit to any of the attractants used during our study period. Please see Baldwin et al. (2022) for additional details on this study.

DISCUSSION

Ultimately, our goal is to develop an IPM approach to manage roof rats in citrus orchards. Our initial efforts centered on developing strategies for monitoring roof rats. We have shown that both remote-triggered cameras and tracking tunnels effectively track changes in roof rat numbers over time. Such monitoring will provide the foundation for an effective IPM program by indicating when and where efforts will be needed to reduce roof rat numbers in orchards.

Our assessment of roof rat movement data identified that roof rats are exclusively using orchard habitats, rather than surrounding fields and adjacent habitats, so monitoring and control efforts should be focused within orchards. We determined that roof rats are moving relatively large distances within orchards. We used this information to help inform bait station and A24 trap distribution within orchards. We selected a distance that we felt would ensure that each roof rat would have access to a minimum of 2-3 bait stations and A24 traps within their home ranges. Although roof rats likely had access to several bait stations and traps, they may not have been using them as extensively as desired based on the low efficacy observed from bait station and trapping efforts. Shrinking distances to 50 m seemed to increase efficacy of bait stations for the one site we tested with this spacing, and other studies have had success with bait station spacing of 35-50 m (e.g., Whisson et al. 2004, Baldwin et al. 2014). It could be that even though roof rats are moving extensive distances throughout the orchards, they may need shorter intervals between traps and bait stations to increase encounter rates with these devices. Additional testing of efficacy for such distances is warranted to see if this proves effective. The ultimate goal is to develop a distance that leads to effective control while minimizing costs and potential environmental exposure, thus the desire to use the widest spacing possible that still ensures effective control.

It was surprising to note that the A24 traps were completely ineffective for the 3 sites that lacked a platform. The A24 traps have often been successful in island conservation efforts (Carter et al. 2016, Shiels et al. 2019, Gronwald and Russell 2022), but they are placed at ground level at these island locations, thereby providing the rats with easy access to the trap trigger. Our results suggest that platforms are needed to yield reductions in roof rat numbers when the traps are placed higher up in the trees, but further testing is needed to verify this. Additional research is underway to build on this information to develop an IPM program that will provide effective management of this invasive species in citrus orchards.

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