A. Cover Page

1. Project Title: Developing and testing an IPM approach for managing roof rats in citrus.

2. Project Leaders:

Aaron B. Shiels, Ph.D.
Research Scientist and Rodents Project Leader
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USDA-APHIS-WS
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3. Cooperators: NA

4. CDFA Funding Request Amount/Other Funding: PY 1 (2022-2024) = $25,078

5. Agreement Manager:

Julie Siegel
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B. Executive Summary

1. Problem: Roof rats (*Rattus rattus*) cause extensive damage in a number of tree crops including citrus. Roof rat populations seem to be expanding and growing throughout many agricultural regions in CA, yet management options for limiting this damage have been largely unsuccessful. The development of an IPM program could greatly reduce this damage, but we currently lack a good understanding of the efficacy of management tools for roof rats in citrus. Citrus is an important commodity in California. Collectively, oranges, lemons, tangerines, and grapefruits were worth >$2.4 billion to California in 2018 (California Agricultural Statistics Review 2018-2019). Effective management of roof rats in citrus is needed to protect this valuable commodity.

2. Objectives, Approach, and Evaluation: We have multiple objectives for this project. They include: 1) developing an IPM program to manage roof rats in citrus, 2) comparing efficacy of the IPM and rodenticide-only management programs, 3) comparing costs of IPM and rodenticide-only management programs, and 4) collating all information to identify the most cost-effective and efficacious management strategy. Traditional roof rat management, and management for rodents in many agricultural systems, often entails using a single rodenticide application period once a year to knock down rodent populations. This approach may reduce rodent numbers over a short period, but invariably allows the rodent populations to rebound, often causing as many problems the subsequent year as the year prior. A plan that keeps rodent numbers low throughout the year may prove to be more efficacious and cost effective. Likewise, incorporating multiple tools and strategies into a management plan reduces the likelihood that rodents will adapt to any one management tool. To that end, our goal for this project is to develop and test the efficacy and cost effectiveness of an IPM program for managing roof rats in citrus orchards. We will incorporate information from current and recently completed projects to develop an IPM plan at the beginning of the project. This plan will include the use of indexing tools to monitor roof rat numbers at the start of the project, and at set intervals throughout the project to assess the effectiveness of our management program. We will use a combination of elevated bait stations using either or both of diphacinone and chlorophacinone products depending on trials underway. We will also incorporate trapping as part of this IPM program to help reduce and maintain low numbers of roof rats. We will use movement data previously collected from roof rats to determine proper spacing for these roof rat removal tools. This IPM program will be implemented for a full year to determine longer-term effectiveness of this approach. These trials will be conducted in multiple citrus orchards in the Central Valley.

   Concurrent with these IPM trials, we will also operate a more traditional approach for managing roof rats that will include a single rodenticide application period. For this approach, we will implement a bait application period (~4-6 weeks) in the same manner as that which we will use for the IPM program. However, this will be the only removal effort used for the entire year. We will then document changes in roof rat numbers throughout the year. We will keep track of labor and material costs for both the IPM and single rodenticide application strategies to allow for a comparison of both efficacy of each management approach (as measured by change in roof rat numbers over the entire year), as well as the total cost of each management strategy. Concluding thoughts will be provided as to the tradeoffs between altering strategies to lower costs vs. a potential reduction in effectiveness of the management program. This project will be considered a success if we can establish a management program for roof rats in citrus that will prove to be both efficacious and cost effective.

3. Audience: Citrus growers are expected to be the primary beneficiaries of this project. This could have a substantial impact on California agriculture given the high value of citrus in the state. Although this research is targeted toward citrus production, the results may be applicable to other orchard systems as well, thereby increasing the value of this project.

C. Justification

1. CDFA VPCRAC Mission and Responsibilities: At several previous meetings, VPCRAC has identified projects that lead to more effective management of roof rats in citrus as a top priority. Both PIs on this project are currently involved in projects that are setting the foundation for addressing this issue. This proposed project will build off some of this early research. It is important to note that roof rats are invasive rodents that cause extensive agricultural damage throughout California and globally. As such, results from this project may have substantial applicability across many tree crops in California, and potentially to other parts of the U.S. and globally. Additionally, roof rat burrowing activity can potentially damage irrigation infrastructure, they pose substantial human health and safety risks both through disease and parasite transmission and through food safety concerns, and they can have substantial negative impacts to native wildlife through predation, disease transmission, and by outcompeting them for limited resources. As such, the development of effective management strategies for roof rats fits very squarely within the VPCRAC mission.

2. Impact: Rats (*Rattus* spp.) are a common and very damaging invasive pest found throughout much of the world, with one projection of damage caused by rats in the U.S. estimated at $19 billion annually (Pimentel et al. 2005). Although much of the damage they cause occurs in residential areas, they are also common agricultural pests. In particular, nut and tree fruit crops can incur substantial damage from rats when present. For example, roof rats (*Rattus rattus*) cause an estimated 5–10% loss in developing macadamia nut crops in Hawaii each year (Tobin et al. 1997). Furthermore, roof rats cause frequent damage to citrus crops (Worth 1950), with anecdotal information suggesting roof rat damage is on the rise in citrus orchards in California. Effective management options for these invasive rodents are needed to minimize losses in these orchard systems, yet little seems to work for roof rats in citrus orchards (Sun Pacific, pers. comm.).

   The UC IPM Pest Management Guidelines for citrus (https://www2.ipm.ucanr.edu/agriculture/citrus/Roof-Rats/) only lists three management tools for roof rats: 1.) cultural control, 2.) rodenticide baiting, and 3.) trapping. Cultural control primarily involves removing vegetative materials from orchards to help deter roof rats, but the practicality of this approach is substantially limited given that the trees themselves generally provide ample cover for rats. This leaves rodenticides and trapping as the two primary tools for managing roof rats in citrus. For rodenticides, we are aware of no studies officially testing their efficacy against roof rats in citrus. Furthermore, only within the last 2 years has rodenticide application been approved by the California Department of Pesticide Regulation for use in citrus orchards during the bearing season, thereby opening up a new potential strategy that could be highly effective against roof rats. Rodenticides are generally very effective options for managing roof rats (e.g., Baldwin et al. 2014a). Current research will determine if this is the case in citrus orchards, as well. If so, rodenticides will likely constitute a valuable part of an IPM program for roof rat control. That said, exclusive use of rodenticides can sometimes lead to problems such as bait avoidance and rodenticide resistance. Alternative tools are needed to combine with rodenticide applications to maximize the long-term efficiency and effectiveness of management programs (Baldwin et al. 2014b).

Currently, the only other likely tool to supplement rodenticide applications for roof rats in orchards is trapping. Snap traps and cage traps have historically been the two primary traps available for roof rats, but both require checking traps frequently to remove captured individuals and to reapply bait. The recent introduction of the A24 trap into the U.S. has the potential to greatly increase the utility of trapping as a management tool in that the traps allow for the capture of up to 24 rats without the need to check or reset. This could result in substantial savings in labor costs, making trapping a more viable tool for managing roof rats in orchards.

Both of these tools hold potential promise in helping to manage roof rats in citrus, but consideration must be made as to how these tools are distributed throughout an orchard to balance efficacy with cost effectiveness. Our recent research focusing on rat movement patterns has shown that spacing these devices approximately every 250 feet will be ideal. We have also completed analysis on an indexing strategy that will allow us to track changes in roof rat numbers over time. Collectively, this information will all be combined into an IPM program that will be tested for a full year to determine how effective this program can be at both removing roof rats from citrus orchards, as well as keeping these populations from rebounding within the orchards. We will also assess the material and labor costs of this IPM program to provide growers information on both the efficacy and cost effectiveness of this IPM program.

3. Long-Term Solutions: Rats cause extensive damage to agricultural products each year (Pimentel et al. 2005), and based on feedback from numerous growers and PCAs, damage has become increasingly common in citrus in recent years. CDFA's rodenticide labels have not traditionally allowed for bait application within orchards during the bearing season, which has been substantially limiting in citrus where fruit is on the trees almost year-round. New changes to the CDFA diphacinone label now allow for bait application within elevated bait stations during the bearing season. A new chlorophacinone bait may soon be available for similar use if proven effective, as well. That said, more than one tool is needed to develop an effective IPM strategy for managing roof rats in citrus. Trapping is the most likely alternative. The A24 trap is one potential option, although snap trapping or live trapping could be a consideration as well. Collectively, a combined bait application and trapping program could provide a longer-term solution to manage this increasingly common agricultural pest for citrus growers.

4. Related Research: To effectively manage roof rats, we have to be able to monitor for changes in rat population size. Baldwin et al. (2014a) developed an index that used remote-triggered cameras in almonds to monitor roof rat populations. However, the effectiveness of indices can vary across cropping systems (Engeman and Witmer 2000). Therefore, following Whisson et al. (2005), we have developed two indices using tracking tunnels and remote-triggered cameras in citrus to accurately reflect rat populations in this cropping system. We have also tested potential attractants for roof rats, and have identified a commercial attractant (Liphatech Rat & Mouse Attractant) that is highly attractive to roof rats. We will use this in our proposed study.

   Chlorophacinone and diphacinone baits have effectively controlled roof rats in a number of locations and situations (Claffey et al. 1986, Donlan et al. 2003, Witmer et al. 2007). In particular, Baldwin et al. (2014a) determined that 0.005% diphacinone-treated oats

were highly effective against roof rats in almond orchards. Interestingly, 0.005% chlorophacinone-treated oats were not found to be overly efficacious, yet studies have documented efficacy with chlorophacinone in other settings (e.g., Whisson et al. 2004). We currently have a project underway that is addressing the efficacy of both a diphacinone and chlorophacinone bait in elevated bait stations to determine their effectiveness at controlling rats in orchards. We anticipate one or both of these products proving successful at reducing roof rat numbers in citrus orchards, thus we plan to include one or both in our development of an IPM program for roof rats.

Another alternative for controlling roof rats in agricultural systems is trapping. Historically, snap trapping has been used in these settings, but snap trapping requires more consistent labor to set and check traps than baiting. More recently, we have seen an increase in the use of automatic resetting traps that allow for many captures without rebaiting or resetting (Goodnature A24 trap; e.g., Carter et al. 2016, Shiels et al. 2019). These traps are currently in use for removing rats from islands to protect native species, and are now sold in the U.S. for use in commensal and agricultural settings. We are currently addressing their effectiveness in citrus orchards. If effective, they would provide an interesting addition to bait application programs to bolster the concept of IPM in orchards. If not effective, standard snap trapping or targeted live trapping could be used to supplement bait application as part of an IPM approach.

Quinn and Baldwin (2014) previously provided an informative outreach document for orchards to help provide guidance on roof rat management. However, the spacing between bait stations in this document was based on expert opinion given a lack of movement data available for roof rats in California orchards. The PI for this proposal has finished a project that identified movement patterns in roof rats to better define the needed spacing for bait stations and traps in citrus orchards. This information will be used to guide bait station and trap distribution for IPM programs. Lastly, it bears noting that we are seeking cost-share funding from the Citrus Research Board to help defray the costs of this study.

5. Contribution to Knowledge Base: Roof rats (*Rattus rattus*) cause extensive damage in a number of tree crops including citrus. Roof rat populations seem to be expanding and growing throughout many agricultural regions in California, yet management options for limiting this damage have been largely unsuccessful. The development of an IPM program could greatly reduce this damage, but we currently lack a good understanding of the efficacy of management tools for roof rats in citrus. Citrus is an important commodity in California. Collectively, oranges, lemons, tangerines, and grapefruits were worth >$2.4 billion to California in 2018 (California Agricultural Statistics Review 2018-2019). Effective management of roof rats in citrus is needed to protect this valuable commodity. We are currently investigating the efficacy of elevated bait stations to determine their efficacy in citrus orchards. Likewise, the development of an automatic repeating trap has increased the practicality of trapping as a roof rat management tool in citrus orchards. Our ongoing investigation will identify the utility of this approach. Collectively, this information, as well as information on roof rat movement patterns and the development of roof rat monitoring tools, will allow us to develop and test the efficacy and cost effectiveness of an IPM approach to manage this damaging, invasive pest. If successful, this IPM approach should at long last provide citrus growers with a

management approach that will limit roof rat damage and food safety concerns in a cost-effective, practical manner.

6. Grower Use: Roof rats pose a food safety risk and cause extensive damage in orchards systems, as outlined previously. Prior to our current and proposed studies, no research had been conducted to address this problem in citrus. Previous research in nut orchards conducted by Baldwin et al. (2014a) led CDFA to alter their 0.005% diphacinone grain label to allow rodenticide application within citrus orchards during the growing season. Before this change, little could often be done to remove roof rats from citrus orchards in an efficacious and cost effective manner. The availability of labor-saving A24 repeating traps now provides another potential strategy for managing roof rats. The foundation for a successful roof rat management program is currently being constructed, but additional research is needed to determine what tools to include into an IPM program for roof rats in citrus, how efficacious an IPM program can be compared to a more conventional rodenticide-only management strategy, and how cost effective these tools are at managing this invasive pest. The development of an efficacious, cost-effective management program for roof rats in citrus would result in reduced damage to trees and fruit, ultimately increasing crop production for growers. This IPM program will be developed to keep roof rats at low numbers within orchards long-term, thereby substantially reducing any food safety concerns associated with this pest. Although this research will most directly benefit growers, these tools will also have applicability to nurseries and packing facilities that experience damage and conflict scenarios associated with roof rats.

Literature Cited

Baldwin, R. A., N. Quinn, D. H. Davis, and R. M. Engeman. 2014a. Effectiveness of rodenticides for managing invasive roof rats and native deer mice in orchards. Environmental Science and Pollution Research 21:5795–5802.

Baldwin, R. A., T. P. Salmon, R. H. Schmidt, and R. M. Timm. 2014b. Perceived damage and areas of needed research for wildlife pests of California agriculture. Integrative Zoology 9:265–279.

Carter, A., S. Barr, C. Bond, G. Paske, D. Peters, and R. van Dam. 2016. Controlling sympatric pest mammal populations in New Zealand with self-resetting, toxicant-free traps: a promising tool for invasive species management. Biological Invasions 18:1723–1736.

Claffey, D. P., M. G. Madon, and R. T. Smith. 1986. An integrated pest management approach to roof rat control in oceanfront riprap, Ventura County, California. Proceedings of the Vertebrate Pest Conference 12:60–65.

Donlan, C. J., G. R. Howald, B. R. Tershy, and D. A. Croll. 2003. Evaluating alternative rodenticides for island conservation: roof rat eradication from the San Jorge Islands, Mexico. Biological Conservation 114:29–34.

Engeman, R. M., and G. W. Witmer. 2000. IPM strategies: Indexing difficult to monitor populations of pest species. Proceedings of the Vertebrate Pest Conference 19:183–189.

Pimentel, D., R. Zuniga, and D. Morrison. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics 52:273–288.

Quinn, N., and R. A. Baldwin. 2014. Managing roof rats and deer mice in nut and fruit orchards. Division of Agriculture and Natural Resources, Publication 8513.

Shiels, A. B., T. Bogardus, J. Rohrer, and K. Kawelo. 2019. Effectiveness of snap and A24-automated traps and broadcast anticoagulant bait in suppressing commensal rodents in Hawaii. Human-Wildlife Interactions 13:226–237.

Tobin, M. E., A. E. Koehler, and R. T. Sugihara. 1997. Effects of simulated rat damage on yields of macadamia nuts. Crop Protection 16:203–208.

Whisson, D. A., R, M. Engeman, and K. Collins. 2005. Developing relative abundance techniques (RATs) for monitoring rodent populations. Wildlife Research 2005:239–244.

Whisson, D. A., J. H. Quinn, K. Collins, and A. Engilis, Jr. 2004. Developing a management strategy to reduce roof rat, *Rattus rattus*, impacts on open-cup nesting songbirds in California riparian forests. Proceedings of the Vertebrate Pest Conference 21:8–12.

Witmer, G. W., F. Boyd, and Z. Hillis-Starr. 2007. The successful eradication of introduced roof rats (*Rattus rattus*) from Buck Island using diphacinone, followed by an irruption of house mice (*Mus musculus*). Wildlife Research 34:108–115.

Worth, C. B. 1950. Field and laboratory observations on roof rats, *Rattus rattus* (Linnaeus), in Florida. Journal of Mammalogy 31:293–304.

D. Objectives: There are multiple objectives for this project. They include: 1) developing an IPM program to manage roof rats in citrus, 2) comparing efficacy of the IPM and rodenticide-only management programs, 3) comparing costs of IPM and rodenticide-only management programs, and 4) collating all information to identify the most cost-effective and efficacious management strategy.

E. Work Plans and Methods (project dates: Mar 1, 2022 to Feb 29, 2024)

1. Work Plan: This proposed project is part of a longer-term tiered project. The initial portion of this study developed indexing protocols to track roof rat population size, and assessed movement patterns of roof rats. This information is currently being used to test the efficacy of three different strategies for reducing roof rat numbers in citrus orchards: 1.) CDFA's Rodent Bait Diphacinone Treated Grain (0.005%), 2.) a 0.005% chlorophacinone soft bait, and 3.) A24 repeating traps. We anticipate fieldwork concluding by October 2023. This efficacy data will then be used to develop an IPM approach managing roof rats in citrus using all previous portions of this longer-term project to help develop this model. We will then compare the efficacy and cost-effectiveness of the IPM model against a rodenticide-only management strategy to determine which approach will be most practical for citrus growers to employ. Our final

task will be the completion of our final report for this project. We anticipate a completion of analyses and the final report by March 31, 2024.

2. Methods: Our initial step will be to incorporate information from current and recently completed projects to develop an IPM plan. This plan will include a combination of indexing tools to monitor changes in roof rat numbers over time, as well as the use of rodenticides and traps to help reduce roof rat numbers within orchards. We will use movement data already collected to inform the proper distribution of traps and bait stations throughout the orchards.

   Once we have developed an IPM approach to test, we will then identify 4 field sites to conduct trials. Each field site will consist of two treatment blocks. We will use the IPM strategy in one of the blocks, while the other block will receive a rodenticide-only treatment program. As previously stated, the IPM approach is yet to be determined, but will likely use bait stations at the start of the study to knock down roof rat populations. For this approach, bait stations will be distributed throughout the study area. The bait stations will be operated for 4-6 weeks. We will determine efficacy of this removal program through pre-and post-treatment indexing strategies (i.e., remote-triggered cameras and tracking tunnels). If roof rats remain in the treatment area, we will deploy traps to further reduce their numbers. The traps we use will depend on the success of our A24 study. If we find that the A24s successfully reduce roof rat numbers, we will use them. If they are unsuccessful, we will use rat-size snap traps in trees. We will continue to monitor roof rat activity quarterly using indexing tools. Trapping will likely be the only additional tool to keep roof rat numbers under control for the remainder of the year, although if roof rat numbers do increase substantially, we may apply additional bait to again knock down the numbers.

   For rodenticide-only blocks, we will deploy a bait application program that is the same as that used in the IPM block. Once the initial baiting program is complete, we will assess efficacy via our indexing program. At that point, no more rat removal efforts will be undertaken. However, we will continue to monitor roof rat activity quarterly to see how roof rat populations rebound in the treated area. We will keep track of labor and material costs for both the IPM and single rodenticide application strategies to allow for a comparison of both efficacy of each management approach (as measured by change in roof rat numbers over the entire year), as well as the total cost of each management strategy. Concluding thoughts will be provided as to the tradeoffs between altering strategies to lower costs vs. a potential reduction in effectiveness of the management program. Special consideration will be given to the potential long-term efficacy and cost effectiveness of each management strategy.

3. Experimental Site: Treatment sites will be determined at the time of the study based on current numbers of roof rats at orchard locations. That said, we anticipate sites occurring in Kern and Tulare Counties.

F. Project Management, Evaluation, and Outreach

1. Management: R. Baldwin will serve as the primary PI for the project and will oversee all aspects of the project ($147,279 of total project budget). A. Shiels will serve as Co-PI

and will be involved extensively in study design and data collection, and will assist in analysis and report/publication writing ($25,078 of total project budget).

2. Evaluation: Success for this project will depend on our ability to identify the best strategy for managing roof rats in citrus based on the tools and methods listed in this proposal. This will involve balancing costs associated with a management program to the longer-term efficacy of each program. Once completed, we will develop a number of outreach materials to convey our findings to citrus growers. Initial efforts will involve providing results of our findings through various seminar and interview opportunities. The PI is a Cooperative Extension Specialist and regularly provides 20-30 presentations and several interviews on rodent management each year. We will also provide popular press and trade magazine articles to further the reach of our findings. Our study results will be particularly important to include into the UC IPM Pest Management Guidelines for citrus. This will be an easy addition, as the PI is the author for the vertebrate section.

   Of particular importance is a previous UC ANR publication on managing roof rats and deer mice in nut and fruit orchards that was coauthored by the PI (http://baldwin.ucdavis.edu/files/1814/7223/7069/Quinn_and_Baldwin_2014.pdf). This has been a useful resource, but it focused exclusively on rodenticide application and lacked information on roof rat movement patterns that are needed to optimize spacing of roof rat management tools. Furthermore, roof rat cover is quite a bit different in citrus crops than in other tree crops given the presence of thick cover year-round. As such, we will either update this previous publication, or more likely, we will create a separate UC ANR publication that will detail how to develop an IPM program for managing roof rats in citrus orchards. From a management perspective, this will be the seminal publication to come out of this project.

G. Budget Narrative

a. Personnel Expenses:

Name & Role on Project: Dr. Aaron Shiels, Rodent Research Scientist, USDA/APHIS/WS/NWRC. Shiels will participate in all parts of the project, and will be most involved in study design, data collection, analysis, and report/publication writing. Funds will be used to exploit Shiels' wildlife damage management expertise in this topic. The outlined tasks and study are not part of the NWRC base mission that would normally occur with NWRC appropriated funds. Shiels will receive salary and benefits for these tasks at the GS13 level. It is anticipated that costs will represent 11% of his annual salary ($12,406 salary January 2022-June 2024 [UC Davis fiscal year]); Fringe benefits on $12,406 is $6,194, following OPM guidelines (opm.gov).

b. Operating Expenses:

Supplies: N/A

Equipment: N/A

Travel ($5,250 total)*:* Shiels will travel from Colorado to California to visit field sites three times to supply assistance.

Trip 1: From Apr 12 to Apr 17, 2022, PI (Shiels) will travel from Fort Collins, Colorado, to anticipated field site in the Bakersfield area (TBD). This travel will correspond with site establishment and initiation of study (and meeting PI Baldwin and SRA II). Travel will include airfare, rental car+gas, hotel, parking at Denver airport, and per diem (opm.gov). As per opm.gov, hotel per diem is $111/night, and meals+incidental expenses (M&IE) is $61/day for Bakersfield, California. Thus, estimates for this 6 days/5 nights duration trip: Airfare ($405), Rental Car (6 days = $304), Gas ($60), Parking at Denver Airport ($10/day = $60), Lodging ($111/night tax exempt x 5 nights = $555), M&IE per diem ($61/day x 6 = $366). Thus, the anticipated 6 days/5 nights trip is estimated to total $1,750.

Trip 2: From Oct 23 to Oct 28, 2022, PI (Shiels) will travel from Fort Collins, Colorado, to anticipated field site in the Bakersfield area (TBD). This travel will correspond with maintenance trapping and indexing (and meeting SRA II, and possibly PI Baldwin). Travel will include airfare, rental car+gas, hotel, parking at Denver airport, and per diem (opm.gov). As per opm.gov, hotel per diem is $111/night, and meals+incidental expenses (M&IE) is $61/day for Bakersfield, California. Thus, estimates for this 6 days/5 nights duration trip: Airfare ($405), Rental Car (6 days = $304), Gas ($60), Parking at Denver Airport ($10/day = $60), Lodging ($111/night tax exempt x 5 nights = $555), M&IE per diem ($61/day x 6 = $366). Thus, the anticipated 6 days/5 nights trip is estimated to total $1,750.

Trip 3: From Mar 14 to Mar 19, 2023, PI (Shiels) will travel from Fort Collins, Colorado, to anticipated field site in the Bakersfield area (TBD). This travel will correspond with maintenance trapping and indexing (and meeting SRA II, and possibly PI Baldwin). Travel will include airfare, rental car+gas, hotel, parking at Denver airport, and per diem (opm.gov). As per opm.gov, hotel per diem is $111/night, and meals+incidental expenses (M&IE) is $61/day for Bakersfield, California. Thus, estimates for this 6 days/5 nights duration trip: Airfare ($405), Rental Car (6 days = $304), Gas ($60), Parking at Denver Airport ($10/day = $60), Lodging ($111/night tax exempt x 5 nights = $555), M&IE per diem ($61/day x 6 = $366). Thus, the anticipated 6 days/5 nights trip is estimated to total $1,750.

Profession/Consulting Services: N/A
Other Expenses: N/A
Indirect Costs: USDA APHIS Overhead is 5.15%, and this will be charged.

c. Other Funding Sources:

Automatic Trap Company:
They will provide $5,000 in in-kind support for the project. This will include all A-24 traps and all attachments and attractants required to properly operate these traps.

H. Budget Template (see attached)

I. Appendices

1. Project Leaders: (see attached – abbreviated CVs for Shiels and Baldwin, and "Current & Pending Support – Exhibit A6)

2. Cooperators: N/A

3. Supporters: (see attached – Automatic Trap Company letter)

2021 VPCRAC Project Proposal
Budget Template

Complete the budget template below by filling in information. This template uses formulas to automatically calculate totals. **Do not** alter the formatting or formulas in cells. Rows may be added to accommodate additional personnel or funding sources, if necessary. Contact the CDFA staff at (916) 262-1102 or David.Kratville@cdfa.ca.gov for help filling out this template.

Project Title:	Developing and testing an IPM approach for managing roof rats in citrus
Project Leader(s):	Roger A. Baldwin, Aaron B. Shiels (this budget sheet is for the portion of the study for Shiels/USDA only)

		2021-2022	2022-2023	2023-2024	Total
A.	**PERSONNEL (name, role, % based on full time salary)**				
	Salary				
	Aaron Shiels, PI involved in all aspects, 11% of full time	$4,154.00	$4,154.00	$4,154.00	$12,462.00
	salary				$0.00
					$0.00
					$0.00
	Salary Total	$4,154.00	$4,154.00	$4,154.00	$12,462.00
	Benefits				
	Aaron Shiels, PI involved in all aspects, 11% of full time	$2,046.00	$2,046.00	$2,046.00	$6,138.00
	benefits				$0.00
					$0.00
					$0.00
	Benefits Total	$2,046.00	$2,046.00	$2,046.00	$6,138.00
	Personnel Cost (A)	$6,200.00	$6,200.00	$6,200.00	$18,600.00
B.	**OPERATING EXPENSES**				
	Supplies				$0.00
	Equipment				$0.00
	Travel	$1,750.00	$1,750.00	$1,750.00	$5,250.00
	Professional/Consultant Services(Cannot exceed $65/hour)				$0.00
	Other				$0.00
	Operating Cost (B)	$1,750.00	$1,750.00	$1,750.00	$5,250.00
	TOTAL Costs (A+B)	$7,950.00	$7,950.00	$7,950.00	$23,850.00
C.	Indirect Costs (Cannot Exceed 10% of Total Costs (A+B))	$409.42	$409.42	$409.42	$1,228.26
	TOTAL CDFA FUNDING REQUESTED (A+B+C)	$8,359.42	$8,359.42	$8,359.42	$25,078.26
D.	**OTHER FUNDING SOURCES**				
	Automatic Trap Company	$5,000.00			$5,000.00
					$0.00
					$0.00
					$0.00
					$0.00
	TOTAL OTHER FUNDING (C)	$5,000.00	$0.00	$0.00	**$5,000.00**
	TOTAL PROJECT BUDGET (A+B+C+D)	$13,359.42	$8,359.42	$8,359.42	$30,078.26

Aaron B. Shiels, Research Scientist – Abbreviated Resume

USDA, APHIS, Wildlife Services
National Wildlife Research Center
4101 LaPorte Ave, Fort Collins, CO. 80521

Email: aaron.b.shiels@usda.gov
Phone: 808-960-5108

Education:

B.S., Denver University, 1998, Environmental Science Department
M.S., University of Nevada, Las Vegas, 2002, Biology Department
Ph.D., University of Hawaii at Manoa, 2010, Botany Department
Postdoctoral Research Associate, USDA, 2011-2015

Employment:

Research Scientist, Rodents Project, USDA, APHIS, WS, National Wildlife Research Center, 2015-current.

Relevant Current Research:

2020 Lead PI for "Effectiveness of an aerial application of diphacinone rodenticide at low bait rate to suppress invasive rodents", Funding: U.S. Army Natural Resources Program; Period: 2020-2021; *the proposed VPCRAC study will not be impacted by this study.*

2020 Lead PI for "Weatherability and palatability of four formulations of zinc phosphide for controlling vole damage to seed-grass farms in the Willamette Valley", Funding: Oregon Seed Council; Period: 2020-2021; *the proposed VPCRAC study will not be impacted by this study.*

2019 Co-PI for "Efficacy testing a novel rat specific toxicant in Norway and black rats". Funding: California Department of Food and Agriculture, Vertebrate Pest Control Research Program; Period: 2019-2021; *the proposed VPCRAC study will not be impacted by this on-going study, as the study will be in final laboratory testing in Oct 2021.*

----------*Research studies below are 100% complete*----------

2020 Lead PI for "Development of an A24 rat trap excluder to prevent nontarget bird entry and impact". Funding: Department of Land and Natural Resources (Hawaii); Period: Feb 2020 to Jan 2021.

2019 Lead PI for "Efficacy and humanness of Goodnature A24 rat+stoat self-resetting traps with Chocolate Lure for use on house mice (*Mus musculus*)". Funding: Automatic Trap Company, Inc.; Period: 2019.

2019 Lead PI for "Test and evaluation of infrared small mammal surveys and tracking tunnels to compare with traditional trapping surveys at airports". Funding: USDA, APHIS, Wildlife Services Operations; Period: 2019-2020.

2018 Lead PI for "Assessment of invasive rat (*Rattus* spp.) control methods in the Waianae Mountains, Oahu". Funding: U.S. Army Natural Resources Program; Period: 2018-2020.

2017 Co-PI for "Management of urban black-tailed prairie dog populations using non-lethal reproductive control". Funding: Botstiber Institute for Wildlife Fertility Control. Period: 2017-2019.

2017 Co-PI for "Restoring ecosystems and biodiversity through development of safe and effective gene drive technologies". Funding: U.S. Department of Defense, Defense Advanced Research Project Agency (DARPA); Period: 2017-2018.

2017 Lead PI for "Invasive rat (*Rattus rattus*) impacts in Luquillo rainforest, Puerto Rico". Funding: University of Puerto Rico & Luquillo LTER; Period: 2017-2018.

2016 Lead PI for "Assessment of an aerial-broadcast rodenticide bait trial to control rats (*Rattus* spp.) in the Waianae Mountains, Oahu". Funding: Oahu Army Natural Resources Program; Period: 2016-2018.

2016 Lead PI for "Biological monitoring and nontarget species impacts during aerial broadcast of rodenticide to remove invasive rats (*Rattus rattus*) from Desecheo Island, Puerto Rico". Funding: U.S. Fish & Wildlife Service; Period: 2016-2017.

Representative Publications:

Shiels, A.B., C.D. Lombard, L. Shiels, and Z. Hillis-Starr. 2020. Invasive rat establishment and changes in small mammal populations on Caribbean islands following two hurricanes. *Global Ecology and Conservation* 22: e00986.

Shiels, A.B., T. Bogardus, J. Rohrer, and K. Kawelo. 2019. Effectiveness of snap and A24-automated traps and broadcast anticoagulant bait in suppressing commensal rodents in Hawaii. *Human-Wildlife Interactions* 13: 226-237.

Shiels, A.B., and G.E. Ramírez de Arellano. 2019. Habitat use and seed removal by invasive rats (*Rattus rattus*) in disturbed and undisturbed rainforest, Puerto Rico. *Biotropica* 51: 378-386.

Shiels, A.B., A.C. Medeiros, E.I. von Allmen. 2017. Shifts in an invasive rodent community favoring black rats (*Rattus rattus*) following restoration of a native forest. *Restoration Ecology* 25: 759-767.

Duron, Q., **A.B. Shiels**, and E. Vidal. 2017. Control of invasive rats on islands and priorities for future action. *Conservation Biology* 31: 761-771.

Shiels, A.B., and D.R. Drake. 2015. Barriers to seed and seedling survival of once-common Hawaiian palms: the role of invasive rats and ungulates. *AoB PLANTS* 7: plv057 (1-10).

Shiels, A.B., W.C. Pitt, R.T. Sugihara, and G.W. Witmer. 2014. Biology and impacts of Pacific island invasive species. 11. *Rattus rattus*, the black rat (Rodentia: Muridae). *Pacific Science* 68: 145-184.

Shiels, A.B., C.A. Flores, A. Khamsing, P.D. Krushelnycky, S.M. Mosher, and D.R. Drake. 2013. Dietary niche differentiation among three species of invasive rodents (*Rattus rattus*, *R. exulans*, *Mus musculus*). *Biological Invasions* 15: 1037-1048.

Pender, R.J., **A.B. Shiels**, L. Bialic-Murphy, and S.M. Mosher. 2013. Large-scale rodent control reduces pre- and post-dispersal seed predation of the endangered Hawaiian lobeliad, *Cyanea superba* subsp. *superba* (Campanulaceae). *Biological Invasions* 15: 213-223.

Exhibit A6 – Current & Pending Support

CURRENT & PENDING SUPPORT

University will provide current & pending support information for Key Personnel identified in Exhibit A2 at time of proposal and upon request from State agency. The "Proposed Project" is this application that is submitted to the State. Add pages as needed.

PI: Roger A. Baldwin

Status (currently active or pending approval)	Award # (if available)	Source (name of the sponsor)	Project Title	Start Date	End Date
Proposed Project	TBD	California Department of Food and Agriculture	Developing and testing an IPM approach for managing roof rats in citrus.	03/01/2022	02/29/2024
Current	NA	Specialty Crop Research Initiative	Scientific challenges and cost-effective management of risks associated with implementation of produce safety regulations	09/01/2020	09/31/2024
Current	NA	California Department of Food and Agriculture	Development of a management program for voles in alfalfa.	09/01/2021	12/31/2022

Aaron B. Shiels

Status	Award #	Source	Project Title	Start Date	End Date
Proposed Project	TBD	California Department of Food and Agriculture	Developing and testing an IPM approach for managing roof rats in citrus.	03/01/2022	02/29/2024
Current	21-7485-1543-RA	California Department of Food and Agriculture	A test of management tools for invasive roof rats	02/01/2021	12/31/2021
Current	NA	Oregon Seed Council	Weatherability and palatability of four formulations of zinc phosphide for controlling vole damage to seed-grass farms in the Willamette Valley	02/01/2021	12/31/2021
Current	NA	U.S. Army Garrison	Effectiveness of an aerial application of diphacinone at low bait rate to suppress invasive rodents	11/01/2020	12/31/2021
Current	NA	U.S. Fish & Wildlife Service	An early assessment of aquatic environmental risk to toxic bait application for the eradication of invasive rats on Aleutian Islands, Alaska	09/30/2020	09/30/2025