A. COVER PAGE

Project Title: The Western Center for Agricultural Health and Safety	
Grant Number: U54 OH07550 **Federal Grant ID** 007550OH16	**Project/Grant Period**: 09/30/2016-09/29/2022
Reporting Period: 09/30/2016-09/29/2022	**Date Submitted**: 2/6/23
Program Director/ Principal Investigator Kent E. Pinkerton, PhD Email: kepinkerton@ucdavis.edu	**Administrative Official Information** Grace Liu UNIVERSITY OF CALIFORNIA, DAVIS 1850 Research Park Dr., Suite 300 University of California-Davis Davis, CA 95618 Phone number: 530-754-7700 Email: giliu@ucdavis.edu EIN: 1946036494A1 UEI: TX2DAGQPENZ5 RECIPIENT ID: 85A36
Change of Contact PD/PI: N/A	
Human Subjects: Yes	**Vertebrate Animals:** Yes
hESC: No	**Inventions/Patents:** No

B. ACCOMPLISHMENTS

B.1. What are the major goals of the project?

The Western Center for Agricultural Health and Safety (WCAHS), based at the University of California, Davis (UC Davis), is a comprehensive, multidisciplinary program dedicated to the understanding and prevention of illness and injury in western agriculture. Our overall goal is to improve the health and safety of farmers, farmworkers, and their families and communities, with special consideration to those issues unique to western agriculture. We aim to be a leader in this field by partnering with diverse stakeholders, conducting innovative multidisciplinary research, providing education that links into established health education networks, and demonstrating effective outreach and translation of all center activities.

The scientific and technical competency of the WCAHS faculty enables innovative goals, in large measure in field-oriented research projects, as well as in interventions, education, and evaluation to further agricultural worker health and safety. To achieve these goals, we have assembled a team of scientists from five schools and colleges (School of Medicine, School of Veterinary Medicine, College of Agricultural and Environmental Sciences, College of Engineering, and College of Letters and Sciences), and over 10 academic departments. Some of the key themes and strengths of our center, which span across several projects and programs, include multilingual health and safety efforts among immigrant farmworkers, respiratory disease from exposures in western dry farming environments, and engineering better ergonomic solutions to reduce acute and cumulative trauma injuries in agriculture.

The center's main area of responsibility includes Arizona, California, Hawaii, and Nevada. California agriculture, measured by sales, is larger than any other state, and when combined with the other three states, the region presents agricultural practices and a workforce population different in many ways from those found in the rest of the country but serves as a model for other states. WCAHS is unique among the NIOSH-funded agricultural centers, located at an internationally renowned research university, which houses both a School of Medicine and a School of Veterinary Medicine, and is a land grant university. The center has developed strong collaborative ties with the College of Agricultural and Environmental Sciences (CAES) and the College of Engineering at UC Davis, in addition to many state agencies, stakeholders, and non-governmental organizations (NGOs) throughout the west. The UC Davis CAES is ranked number one in the world. The California state capitol, Sacramento—12 miles from Davis— is home to the state's Departments of Public Health and Health Care Services, Food and Agriculture, and Environmental Protection, as well as the UC Davis Clinical and Translational Science Center (home of our Evaluation Program) and the UC Davis Health System. This large, diverse, multidisciplinary expertise provides a wealth of resources and experience to the center, as well as access to one of the most occupationally and ethnically diverse agricultural populations and communities in the field.

A major goal of the center has been the application of research findings into practical and effective field solutions. This goal has been achieved by numerous routes including "technology transfer" for engineering solutions developed with WCAHS support, communication of research findings to the diverse agricultural community via multiple routes, and collaborative efforts with the state legislature, state agencies, cooperative extensions, and various stakeholders. We have also advocated for policy changes based on findings from our work and the work of others. Our efforts to improve the health of hired immigrant farmworkers, largely Hispanic, have been a major effort of center investigators.

B.2. What did you accomplish under these goals?

1. Evaluation and Planning

From 2016 to 2022 the Evaluation and Planning Core has provided leadership, vision, and direction for all center cores, affiliates, and stakeholders through center administration. The WCAHS Leadership Group met twice per month to review, prioritize, and advance center activities, as well as provide leadership in convening center faculty and stakeholders in research and advisory meetings.

The Evaluation Team, with the support of the Leadership Group and Center Administration, continued to provide the necessary infrastructure and activities to conduct a comprehensive evaluation, which has been integral to the center's continued success. Over the past six years, the WCAHS Evaluation Team conducted both process and outcomes evaluation and regularly shared the data with the Leadership Group to advance and strengthen the function and success of WCAHS. Examples of the evaluation activity and the utilization of data and related findings are described below.

The Leadership Group, with input from WCAHS partners and investigators, identified emerging agricultural health and safety concerns to address. The Emerging Issues projects over the past six years included 1. sexual harassment in agriculture, 2. cannabis worker health and safety, 3. wildfire smoke exposure, and 4. COVID-19 in agriculture.

2. Outreach

Increased funding to the WCAHS Outreach Core in the 2016–2022 cycle facilitated a dramatic expansion of WCAHS' outreach efforts. Between October 2016 and September 2021, the WCAHS Outreach Core conducted 350 outreach events which reached over 17,000 people and distributed over one million print resources to farmers and farmworkers. The overall goal of the WCAHS Outreach Core was and continues to be advancing agricultural health and safety by facilitating knowledge acquisition and behavior change about occupational risks for illness and injuries in the agricultural industry via translation of research findings and regulatory standards into practical solutions. To realize this goal, the WCAHS Outreach Core: 1) developed and disseminated safety information, resources, and training materials; 2) conducted trainings and events; 3) funded outreach grants; and 4) formed strong relationships with California state agencies, garnering over $5.6 million in additional funds.

3. Pilot/Feasibility

From 2016–2022, WCAHS at the University of California, Davis invested over $700,000 of center funds in research projects. The Pilot/Feasibility Program served as a principal vehicle to (1) support short-term research projects with a high likelihood of leading to further funding from extramural sources; (2) provide funding for investigators and graduate students new to the center; and (3) facilitate the exploration of new and innovative directions with the potential to advance agricultural health and safety.

The Pilot/Feasibility Program funded research that addressed agricultural health and safety in Arizona, California, Hawaii, and Nevada. Applications on a wide range of topics were encouraged. Pilot/Feasibility grants were awarded to graduate students and postdoctoral scholars up to $10,000 and faculty were able request up to $30,000. When excess funds were available, typically carryover from the previous budget year or unallocated emerging issues funds, the amount of funds available for Pilot/Feasibility grants increased and the center was able to fund more than the typical four projects. The Piot/Feasibility Program garnered increased visibility during this funding cycle with 12 submissions in 2016–2017, increasing to 39 applications in 2020–2021. In total, 118 proposal submissions were received from 2016–2022 and funded projects covered a wide range of topics utilizing basic science research methods to those qualitative in nature. For example, projects focused on ATV safety, occupational health and injury surveillance of agricultural workers, and the effects of air quality on farmworker productivity.

From 2016–2022, WCAHS funded a total of 48 Pilot/Feasibility grants, with four conducted in Arizona, 42 in California, one in Hawaii, and one in Nevada. The investigators funded highlight our track record of

successfully reaching graduate students and cooperative extension specialists, as well as attracting established investigators, to explore topics related to agricultural health and safety. Many of the grants funded had aims and outcomes that could be applied broadly to agricultural in the western U.S. and beyond, such as youth operating ATVs, Valley fever (coccidioidomycosis), mental health, and wildfire smoke exposure. Pilot/Feasibility Program outputs include 15 publications and 110 presentations. Funded investigators submitted 36 external grant proposals based on their WCAHS-funded findings, and 11 were funded.

4. Center Research Projects

Project 1

Design, development, and deployment of our *(1)* Aerosol Sampling and Measurement Platform (ASAMP) for extensive air pollution, field sampling, and measurement campaigns throughout California's Sacramento, San Joaquin, and Imperial Valleys and *(2)* Rapid Response Mobile Research Unit (2RMRU) for *in situ* sampling of active wildfires throughout the 2017–2020 California fire seasons has resulted in an extensive and unmatched archive of PM samples available to us and other research groups for chemico-toxicological characterization as a function of particle size, source, composition, atmospheric processing, region, and environmental setting. A subset of these samples has already been thoroughly analyzed over the past six years through our WCAHS research efforts, numerous samples have been gifted to other research groups in the US and internationally for complementary and collaborative research projects, and there is still a vast reserve of samples archived for future research through both our WCAHS renewal and other internal and extramural funding mechanisms.

Through careful establishment of the most robust and scientifically sound methods for *(i)* extracting sampled PM from the collection substrates prior to toxicological testing, *(ii)* administering extracted PM for *in vitro* and *in vivo* studies and *(iii)* providing a full chemical characterization of all PM samples used, we have successfully created a large and rich database on the chemical and toxicological properties of PM as a function of particle size, source, and atmospheric processing. Our studies have implemented cellular markers of inflammation and reactivity in novel cell culture systems, used animal models of healthy and allergic mice, and employed a comprehensive suite of analytical techniques to obtain these data. Results from all these efforts to understand the relative toxicity of different PM sources, including agriculture, wildfires, and vehicular emissions, have culminated in a large body of peer-reviewed publications, numerous presentations at scientific conferences, stakeholder organizations, expert panels, and symposia, as well as invited talks and several interviews through various media outlets. These outreach efforts have made our research highly visible and relevant to the public.

In collaboration with the WCAHS Outreach Core and several other institutions and stakeholder organizations, our research and peer-reviewed results have enabled the creation of a wide array of safety training materials and checklists, including videos and presentations as part of worker training in the field, wildfire safety and training materials, evaluation guidelines for COVID-19 safety and proper facemask use in agricultural settings, safety alerts on the spread of COVID-19 via respiratory droplets, and a survey-based brochure detailing how extreme weather events may impact the work, health, and safety of agricultural employers and farmworkers. These materials have been disseminated widely throughout California to agricultural organizations, advocacy groups, labor contractors, state agencies, and farmworker communities via several mechanisms like extensive mailing campaigns and in-person and virtual training efforts up and down the state. Adapting health promotion and workplace safety strategies to meet the multiple vulnerabilities and diverse needs of farmworkers is critical to successful implementation of workplace

protection and safety measures. Also, these efforts have empowered farmworker communities and stakeholders with knowledge to advocate for change.

An extensive and impressive cohort of high school students, community members, advocacy organizational staff, undergraduates, graduate students, postdoctoral scholars, academic researchers, and visiting scholars have been involved in our studies over the past six years. These efforts and opportunities have provided training and professional development across various disciplines, career stages and trajectories, and public and private sectors. In total, our research efforts have had a positive impact on academia, industry, advocacy, state agencies, and farmworker communities through a confluence of heightened awareness of major issues impacting farmworker health and safety, potential mitigation, adaptation, and regulatory strategies, education, and community outreach, strong interorganizational collaborative partnerships, and career development.

Project 2

Experiments were conducted to examine biosolarization in California agriculture and address barriers to adoption for biosolarization as an alternative to conventional soil fumigation with toxic chemicals. This entailed using major sources of residual biomass in the state, such as hulls and shells from almond processing, as soil amendments to trigger production of natural biopesticides and other pest-inactivating conditions during biosolarization. Following field trials in 2017 that demonstrated control of soil pests immediately following biosolarization, ongoing monitoring of field sites has shown long-term benefits to soil health associated with biosolarization, including persistent pest suppression and elevated plant nutrient content. Specifically, biosolarization guarded against reinfestation by harmful nematodes for approximately two years, while promoting increased levels of plant nutrients in treated soils; by four years post-treatment, soil pest and nutrient properties in biosolarized and untreated soils became more similar. However, ongoing monitoring of soil and almond tree properties at the trial site have shown that certain varieties of almond trees in biosolarized soils exhibit greater trunk diameters and greener canopies than those grown in untreated soils. These are indicators of increased vigor that may lead to improved yield. Industry engagement continues to be an integral element of this project. To further expand the applicability of biosolarization in western agriculture, new regional sources of compatible organic matter soil amendments continue to be explored. Residues from commercial onion processing have proven to be effective in laboratory pest control studies by yielding high levels of biopesticides and phytoparasite control during biosolarization. Across all aspects of the project, direct collaboration with commercial growers and food processors, presentations at industry events, and publication of articles in agricultural trade journals were used to increase grower awareness and promote adoption of biosolarization.

Project 3

In this project, we investigated the effects of strawberry harvest aids on the biomechanical response of workers. We built a simulated harvest aid system that replicates field conditions and conducted field observations and controlled experiments. We monitored workers' productivity in actual strawberry picking operations when using a personal collaborative-robotic system as well as spinal posture when performing a simulated strawberry picking using various harvest aids and picking conditions. The main findings of the project were:

- The harvest aid system built for this study provides an adequate system for replicating field picking conditions.

- The biomechanical response of the spine is affected by how far the harvest aid system is away from the worker, with increased walking distance resulting in reduced lumbar flexion angle and the amount spent in high-risk postures.
- The collaborative robot system investigated in this study seems to provide a substantial increase in worker productivity.
- The robot optimization software tends to serve fast pickers more frequently, which translates into fast pickers harvesting more rows and making more money, creating a potential for inequity among workers.
- Preliminary simulation results of the robotic system showed that it is possible to increase service equity among the harvesting crew without penalizing the overall harvest efficiency. Follow up biomechanical confirmation is needed to assess the effects on worker.

Project 4

This project focused on creating outreach materials heat-related illness (HRI) based on previous research results. The developed video and training materials were used in nine trainings: three for 54 English-speaking supervisors, two for 51 Spanish-speaking supervisors, three for 44 Spanish-speaking workers, and one for 36 Spanish- and Mixteco-speaking workers. Each attending supervisor received the new package of materials to use for future trainings. Feedback has been overwhelmingly positive. In total, we have mailed out over 70,000 packages of printed materials. Both the video and training materials have been featured in NIOSH's monthly eNews as well as in the WCAHS newsletter. Short videos on the importance of heat-related illness in English and Spanish were posted to WCAHS' website and YouTube channel in 2020 and have received 897 views. Short videos in Spanish with information on water, shade, and rest breaks for HRI prevention were posted to YouTube in October 2022.

There were several findings based on analyses of the study data:

- During hotter weather, work shift lengths were shorter. When the ambient temperature was greater than 35°C (95°F) the average workday is 55 minutes shorter. This was most likely based on decisions by managers and would reduce worker productivity.
- Workers who are paid piece-rate have higher activity levels than workers paid hourly at lower temperatures, but at temperatures over 35°C (95°F) piece-rate workers reduce their activity to below that of hourly workers. Piece-rate workers increase the rate of activity during moderate temperatures, which may cause a greater risk for HRI; however, flexibility about pay arrangements depending on the temperature may help prevent HRI.
- When considering environmental heat and activity level throughout the workday, hotter temperature in the previous 15-minute interval is associated with a lower activity level. The work rate was also affected by the worker's age, gender, BMI, and dehydration at the end of the workday.
- Even when farms are following Cal/OSHA's heat-related illness prevention regulations for worker training and hydration, workers experience risk of HRI measured by elevated core body temperature. Risk factors for elevated core body temperature are higher ambient temperatures, being male, having a higher work rate, and having a higher BMI.
- Anemia can cause fatigue and reduced productivity. Anemia was rare among study participants and not associated with reporting fatigue at work. Most workers participating in the study had a BMI categorized as overweight or obese.

Project 5

At the group-level, we identified dairy cows that present an increased risk of exposure to zoonotic pathogens (microorganism such as bacteria, viruses, or parasites that can cause infection or disease in both humans

and animals typically transferred via the fecal-oral route) by collecting fecal samples from 528 individual dairy cows. Production stage (calf, heifer, dry, lactating, and other) was used to group the cows with-in the dairy, and the cows were housed across three participating dairies in California's San Joaquin Valley. To estimate risk of exposure with more granularity, production stage was stratified into two natural substages (calf: pre vs. post weaned, heifer: pre vs. post 1st pregnancy, dry: far-off vs. close-up to delivering calf, lactation: high vs. low milk production, and other: hospital cows vs. cull). These risk indices were pared with nearly 1,600 observed occupation tasks over roughly 64 hours and 24 dairy worker occupation tasks to estimate risk profiles across the dairy. To differentiate the risk, we also investigated fecal-oral transmission potential by observing twelve risky-protective occupational behaviors with direct transmission potential (touch face, touch mouth, visible fecal splash, eat/drink), indirect transmission potential (touch dairy surface, touch cow, tail whip, spray hose, use phone), and low transmission potential (wash hands, change PPE, use tractor). These results can help promote more awareness and potentially focused safety trainings in the areas of the dairy with elevated risk profiles.

B.3. Competitive Revisions/Administrative Supplements

Year 6 – additional year of funding through NIOSH. See B2 for accomplishments associated with Year 6 activities.

B.4. What opportunities for training and professional development did the project provide?

The center provided professional development opportunities through its Emerging Issues, Outreach, Pilot/Feasibility Program, and core research projects. Those awarded grants were funded to conduct research and were given the opportunity to speak at center-wide events. Some awardees were assisted with applications to R01 grants, received support with publications, and their research was shared on the WCAHS website. See individual core and research project reports for more information.

B.5. How did you disseminate the results to communities of interest?

As reported more extensively in the Administration and Evaluation Core report and Outreach Core report, as well as in individual research project reports, WCAHS devotes substantial effort to expand the reach of research and outreach findings through comprehensive communications efforts. This has been achieved through newsletters, social media, website content, attendance at ag-related events, and UC Davis events. These efforts are in addition to traditional avenues such as peer-review journal publications and academic conferences.

Our efforts to further disseminate our findings to the community have been achieved through newsletters, social media, website content, attendance at "ag-related" events, and UC Davis events. The Western Center for Agricultural Health and Safety provides research, education, and training resources on its website: aghealth.ucdavis.edu. These efforts are in addition to traditional avenues such as peer-review journal publications and academic conferences.

B.6 - What do you plan to do during the next reporting period to accomplish the goals?

N/A

C. PRODUCTS

C.1. Publications, conference papers, and presentations

2021

Axelrod, R., Palma Miner, L., VanderGheynst, J. S., Simmons, C. W., & Fernandez-Bayo, J. D. (2021). Soil Application of Almond Residue Biomass Following Black Soldier Fly Larvae Cultivation. Frontiers in Sustainable Food Systems, 5, 188.

D'Evelyn SM, Vogel CFA, Bein KJ, Lara B, Laing EA, Abarca RA, Zhang Q, Li L, Li J, Nguyen TB, Pinkerton KE. Differential inflammatory potential of particulate matter (PM) size fractions from Imperial Valley, CA. Atmospheric Environment 2021 Jan 1;244:117992. doi: 10.1016/j.atmosenv.2020.117992. Epub 2020 Oct 14.

Fenske RA & Pinkerton KE (2021): Climate Change and the Amplification of Agricultural Worker Health Risks, Journal of Agromedicine, DOI:10.1080/1059924X.2021.1849211

Langer CE, Mitchell DC, Armitage TL, Moyce SC, Tancredi DJ, Castro J, Vega-Arroyo AJ, Bennett DH, Schenker MB. 2021. Are Cal/OSHA Regulations protecting farmworkers in California from heat-related illness? Journal of Occupational and Environmental Medicine. 63(6):532-9. doi: 10.1097/JOM.0000000000002189

Reid, A., Ronda-Perez, E., & Schenker, M. B. (2021). Migrant workers, essential work, and COVID-19. American Journal of Industrial Medicine, 64(2), 73-77.

Riden HE, Felt E, Pinkerton KE, "The Impact of Climate Change and Extreme Weather Conditions on Agricultural Health and Safety in California" in Climate Change and Global Public Health, Second Edition, KE Pinkerton and WN Rom, Editors, Humana Press, Springer, New York.

Shea, E., Wang, Z., Allison, B., & Simmons, C. (2021). Alleviating phytotoxicity of soils biosolarized with almond processing residues. Environmental Technology & Innovation, 23, 101662.

Willson, B. E., Gee, N. A., Willits, N. H., Li, L., Zhang, Q., Pinkerton, K. E., & Lasley, B. L. (2021). Effects of the 2018 Camp Fire on birth outcomes in non-human primates: Case-control study. Reproductive Toxicology, 105, 128-135.

2020

Achmon, Y., Claypool, J. T., Fernández-Bayo, J. D., Hernandez, K., McCurry, D. G., Harrold, D. R., …& Simmons, C. W. (2020). Structural changes in bacterial and fungal soil microbiome components during biosolarization as related to volatile fatty acid accumulation. Applied Soil Ecology, 153, 103602.

Adaska, J.M., Ekong, P.S., Clothier, K.A., Williams, D.R., Rossitto, P.V., Lehenbauer, T.W., Atwill, E.R., Li, X. and Aly, S.S. (2020). Bayesian estimation of diagnostic accuracy of fecal culture and PCR-based tests for the detection of Salmonella enterica in California cull dairy cattle. PeerJ, 8, e8310.

Daly, A., Schenker, M. B., Ronda-Perez, E., & Reid, A. (2020). Examining the Impact of Two Dimensions of Precarious Employment, Vulnerability and Insecurity on the Self-Reported Health of Men, Women and Migrants in Australia. International journal of environmental research and public health, 17(20), 7540.

Fernandez-Bayo, J. D., Shea, E. A., Parr, A. E., Achmon, Y., Stapleton, J. J., VanderGheynst, J. S., ... & Simmons, C. W. (2020). Almond processing residues as a source of organic acid biopesticides during biosolarization. Waste Management, 101, 74-82.

Moyce, S., Armitage, T., Mitchell, D., & Schenker, M. (2020). Acute kidney injury and workload in a sample of California agricultural workers. American journal of industrial medicine, 63(3), 258-268.

Moyce, S., Mitchell, D., Vega, A., & Schenker, M. (2020). Hydration choices, sugary beverages, and kidney injury in agricultural workers in California. Journal of Nursing Scholarship, 52(4), 369-378.

Ogorodnik, E., Karsai, A., Wang, K. H., Liu, F. T., Lo, S. H., Pinkerton, K. E., ... & Liu, G. Y. (2020). Direct Observations of Silver Nanowire-Induced Frustrated Phagocytosis among NR8383 Lung Alveolar Macrophages. The Journal of Physical Chemistry B.

Peng, C., Vougioukas, S.G. (2020). Deterministic predictive dynamic scheduling for crop-transport co-robots acting as harvesting aids. Computers and Electronics in Agriculture, 178, 105702. https://doi.org/10.1016/j.compag.2020.105702

Shea, E., Fernandez-Bayo, J. D., Pastrana Leon, A. M., & Simmons, C. (2020). Identification and Evaluation of Volatile Organic Compounds Evolved During Solarization with Almond Hull and Shell Amendments. Journal of the Air & Waste Management Association.

Vidyarthi, S. K., & Simmons, C. W. (2020). Characterization and management strategies for process discharge streams in California industrial tomato processing. Science of The Total Environment, 723, 137976.

Riden HE, Giacinto R, Wadsworth G, Rainwater J, Andrews T, Pinkerton KE. Wildfire Smoke Exposure: Awareness and Safety Responses in the Agricultural Workplace. Journal of agromedicine. 2020 February 11:1-9. PubMed PMID: 32043423; DOI: 10.1080/1059924X.2020.1725699.

Riden, H. E., Schilli, K., & Pinkerton, K. E. (2020). Rapid response to COVID-19 in agriculture: a model for future crises. Journal of Agromedicine, 25(4), 392-395.

Vidyarthi, S. K., & Simmons, C. W. (2020). Characterization and management strategies for process discharge streams in California industrial tomato processing. Science of The Total Environment, 723, 137976.

Presentations:

Fathallah, F.A. (Invited Speaker) and Vougioukas, S. Personal Collaborative Robots in Agriculture (Virtual). Robotics Track, Session on Emerging Applications. ErgoX Symposium- Virtual/Chicago, IL. October 14, 2020. 40 attendees.

Pinkerton, KE, Riden HE. (Invited speakers). "Double jeopardy: Effects of wildfires and COVID-19 on California" National Academies of Sciences, Engineering and Medicine (NASEM), Board on Agriculture and Natural, (12/8/20).

Riden HE. "Improving agricultural health and safety through targeted education and training," American Public Health Association Annual Conference, October 27, 2020.

Riden HE. "Extreme weather events – differing perspectives and safety impacts in agriculture," American Public Health Association Annual Conference, October 27, 2020.

Schenker. "Heat stress risks and outcomes among California farmworkers." WCAHS Seminar Series (online). November 2, 2020.

2019

Achmon, Y., Dowdy, F. R., Simmons, C. W., Zohar-Perez, C., Rabinovitz, Z., & Nussinovitch, A. (2019). Degradation and bioavailability of dried alginate hydrocolloid capsules in simulated soil system. Journal of Applied Polymer Science, 136(43), 48142.

Chase, J. A., Partyka, M. L., Bond, R. F., & Atwill, E. R. (2019). Environmental inactivation and irrigation-mediated regrowth of Escherichia coli O157: H7 on romaine lettuce when inoculated in a fecal slurry matrix. PeerJ, 7, e6591.

Fernández-Bayo, J.D., Hestmark, K.V., Claypool, J.T., Harrold, D.R., Randall, T.E., Achmon, Y., Stapleton, J.J., Simmons, C.W. and VanderGheynst, J.S. (2019). The initial soil microbiota impacts the potential for lignocellulose degradation during soil solarization. Journal of applied microbiology, 126(6), 1729-1741.

Hestmark, K.V., Fernández-Bayo, J.D., Harrold, D.R., Randall, T.E., Achmon, Y., Stapleton, J.J., Simmons, C.W. and VanderGheynst, J.S. (2019). Compost induces the accumulation of biopesticidal organic acids during soil biosolarization. Resources, Conservation and Recycling, 143, 27-35.

Hamilton ER, Hale JM, Savinar R. Immigrant Legal Status and Health: Legal Status Disparities in Chronic Conditions and Musculoskeletal Pain Among Mexican-Born Farm Workers in the United States. Demography. **2019 February;**56(1):1-24. PubMed PMID: 30519846; DOI: 10.1007/s13524-018-0746-8.

Hamilton ER, Hale JM, Savinar R. Immigrant Legal Status and Health: Legal Status Disparities in Chronic Conditions and Musculoskeletal Pain Among Mexican-Born Farm Workers in the United States. Demography. **2019 Februar**y;56(1):1-24. PubMed PMID:30519846.

Mack SM, Madl AK, Pinkerton KE. Respiratory Health Effects of Exposure to Ambient Particulate Matter and Bioaerosols. Comprehensive Physiology. 2019 December 18;10(1):1-20. PubMed PMID: 31853953; DOI: 10.1002/cphy.c180040.

Mack S, Shin J, Ahn Y, Castañeda AR, Peake J, Fulgar C, Zhang J, Cho Y, Pinkerton KE. Age-Dependent Pulmonary Reactivity to House Dust Mite Allergen: A Model of Adult-Onset Asthma? American journal of physiology. Lung cellular and molecular physiology. **2019 March 6**. PubMed PMID: 30840481.

Pinkerton KE, Chen CY, Mack SM, Upadhyay P, Wu CW, Yuan W. Cardiopulmonary Health Effects of Airborne Particulate Matter: Correlating Animal Toxicology to Human Epidemiology. Toxicologic pathology. 2019 December;47(8):954-961. PubMed PMID: 31645209; PubMed Central PMCID: PMC6911013; DOI: 10.1177/0192623319879091.

Pinkerton, K. E., Felt, E., & Riden, H. E. (2019). Extreme weather resulting from global warming is an emerging threat to farmworker health and safety. Journal of agricultural safety and health, 25(4), 189-190.

Vega-Arroyo, A. J., Mitchell, D. C., Castro, J. R., Armitage, T. L., Tancredi, D. J., Bennett, D. H., & Schenker, M. B. (2019). Impacts of weather, work rate, hydration, and clothing in heat-related illness in California farmworkers. American journal of industrial medicine, 62(12), 1038-1046.

Wadsworth, G., Courville, M., & Schenker, M. (2019). Pay, power, and health: HRI and the agricultural conundrum. Labor Studies Journal, 44(3), 214-235.

Wu CW, Yau T, Fulgar CC, Mack SM, Revilla AM, Kenyon NJ, Pinkerton KE. Long-Term Sequelae of Smoking and Cessation in Spontaneously Hypertensive Rats. Toxicologic pathology. 2019 December 24:192623319893312. PubMed PMID: 31870229; DOI: 10.1177/0192623319893312.

2018

Barquera, S., Schillinger, D., Aguilar-Salinas, C. A., Schenker, M., Rodríguez, L. A., Hernández-Alcaraz, C., & Sepúlveda-Amor, J. (2018). Collaborative research and actions on both sides of the US-Mexico border to counteract type 2 diabetes in people of Mexican origin. Globalization and Health, 14(1), 1-10.

Borelli MR, Riden HE, Bang H, Schenker MB. Protocol for a cluster randomized controlled trial to study the effectiveness of an obesity and diabetes intervention (PASOS) in an immigrant farmworker population. BMC public health. 2018 July 9;18(1):849. PubMed PMID: 29986676; PubMed Central PMCID: PMC6038353.

Castañeda AR, Vogel CFA, Bein KJ, Hughes HK, Smiley-Jewell S, Pinkerton KE. Ambient particulate matter enhances the pulmonary allergic immune response to house dust mite in a BALB/c mouse model by augmenting Th2- and Th17-immune responses. Physiological reports. 2018 September;6(18):e13827. PubMed PMID: 30230272; PubMed Central PMCID: PMC6144457.

Castañeda AR, Pinkerton KE, Bein KJ, Magaña-Méndez A, Yang HT, Ashwood P, Vogel CFA. Ambient particulate matter activates the aryl hydrocarbon receptor in dendritic cells and enhances Th17 polarization. Toxicology letters. 2018 April 22;292:85-96. PubMed PMID: 29689377.

Drummond, J. D., Boano, F., Atwill, E. R., Li, X., Harter, T., & Packman, A. I. (2018). Cryptosporidium oocyst persistence in agricultural streams–a mobile-immobile model framework assessment. Scientific reports, 8(1), 1-8.

Fernández-Bayo, J. D., Stapleton, J. J., Achmon, Y., VanderGheynst, J. S., & Simmons, C. W. (2018). The role of organic amendment stability in soil biosolarization efficacy. In IX International Symposium on Soil and Substrate Disinfestation 1270 (pp. 161-168).

Fernandez-Bayo, J. D., Yazdani, R., Simmons, C. W., & VanderGheynst, J. S. (2018). Comparison of thermophilic anaerobic and aerobic treatment processes for stabilization of green and food wastes and production of soil amendments. Waste Management, 77, 555-564.

Hopkins LE, Laing EA, Peake JL, Uyeminami D, Mack SM, Li X, Smiley-Jewell S, Pinkerton KE. Repeated Iron-Soot Exposure and Nose-to-brain Transport of Inhaled Ultrafine Particles. Toxicologic pathology. 2018 January;46(1):75-84. PubMed PMID: 28914166

Kemmick Pintor, J., Mitchell, D. C., & Schenker, M. B. (2019). Exploring the role of depression as a moderator of a workplace obesity intervention for Latino immigrant farmworkers. Journal of Immigrant and Minority Health, 21(2), 383-392.

Moyce, S., Hernandez, K., & Schenker, M. (2019). Diagnosed and undiagnosed diabetes among agricultural workers in California. Journal of Health Care for the Poor and Underserved, 30(4), 1289-1301.

Moyce SC, Schenker M. 2018. Migrant workers and their occupational health and safety. Annual review of public health. 39:351-65. https://doi.org/10.1146/annurev-publhealth-040617-013714

Pace, S. A., Yazdani, R., Kendall, A., Simmons, C. W., & VanderGheynst, J. S. (2018). Impact of organic waste composition on life cycle energy production, global warming and Water use for treatment by anaerobic digestion followed by composting. Resources, Conservation and Recycling, 137, 126-135.

Rice MB, Malea NM, Pinkerton KE, Schwartz J, Nadeau KC, Browner CM, Whitehouse S, Thurston GD. Realizing the Paris Climate Agreement to Improve Cardiopulmonary Health: Where Science Meets Policy. Annals of the American Thoracic Society. 2018 April 13. PubMed PMID: 29652522.

Zhang J, Fulgar CC, Mar T, Young DE, Zhang Q, Bein KJ, Cui L, Castañeda A, Vogel CFA, Sun X, Li W, Smiley-Jewell S, Zhang Z, Pinkerton KE. TH17-Induced Neutrophils Enhance the Pulmonary Allergic Response Following BALB/c Exposure to House Dust Mite Allergen and Fine Particulate Matter From California and China. Toxicological sciences: an official journal of the Society of Toxicology. 2018 August 1;164(2):627-643. PubMed PMID: 29846732; PubMed Central PMCID: PMC6061684.

Underwood E. July 18, 2018. Unhealthy work: Why migrants are especially vulnerable to injury and death on the job. Retrieved January 19, 2022, from https://knowablemagazine.org/article/society/2018/unhealthy-work-why-migrants-are-especially-vulnerable-injury-and-death-job

2017

Achmon, Y., Fernández-Bayo, J. D., Hernandez, K., McCurry, D. G., Harrold, D. R., Su, J., ... & Simmons, C. W. (2017). Weed seed inactivation in soil mesocosms via biosolarization with mature compost and tomato processing waste amendments. Pest management science, 73(5), 862-873.

Allison, B. J., & Simmons, C. W. (2017). Valorization of tomato pomace by sequential lycopene extraction and anaerobic digestion. Biomass and bioenergy, 105, 331-341.

Bayram, H., Bauer, A. K., Abdalati, W., Carlsten, C., Pinkerton, K. E., Thurston, G. D., ... & Takaro, T. K. (2017). Environment, global climate change, and cardiopulmonary health. *American journal of respiratory and critical care medicine*, *195*(6), 718-724.

Castañeda AR, Bein KJ, Smiley-Jewell S, Pinkerton KE. Fine particulate matter (PM_{2.5}) enhances allergic sensitization in BALB/c mice. Journal of toxicology and environmental health. Part A. 2017;80(4):197-207. PubMed PMID: 28494199.

Ceballos, S. J., Yu, C., Claypool, J. T., Singer, S. W., Simmons, B. A., Thelen, M. P., ... & VanderGheynst, J. S. (2017). Development and characterization of a thermophilic, lignin degrading microbiota. Process Biochemistry, 63, 193-203.

Chase, J. A., Atwill, E. R., Partyka, M. L., Bond, R. F., & Oryang, D. (2017). Inactivation of Escherichia coli O157: H7 on romaine lettuce when inoculated in a fecal slurry matrix. Journal of food protection, 80(5), 792-798.

Christensen S, Jaffar Z, Cole E, Porter V, Ferrini M, Postma B, Pinkerton KE, Yang M, Kim YJ, Montrose L, Roberts K, Holian A, Cho YH. Prenatal environmental tobacco smoke exposure increases allergic asthma risk with methylation changes in mice. Environmental and molecular mutagenesis. 2017 July;58(6):423-433. PubMed PMID: 28543436; PubMed Central PMCID: PMC5513771.

Chu S, Baker MR, Leong G, Letcher RJ, Gee SJ, Hammock BD, Li QX. Exploring adduct formation between human serum albumin and eleven organophosphate ester flame retardants and plasticizers using MALDI-TOF/TOF and LC-Q/TOF. Chemosphere. 2017 August; 180:169-177. PubMed PMID: 28407546; PubMed Central PMCID: PMC5494263.

Fathallah, F., & Duraj, V. (2017). Small changes make big differences: the role of ergonomics in agriculture. Resource Magazine, 24(6), 12-13.

Fernández-Bayo, J. D., Achmon, Y., Harrold, D. R., Claypool, J. T., Simmons, B. A., Singer, S. W., ... & Simmons, C. W. (2017). Comparison of soil biosolarization with mesophilic and thermophilic solid digestates on soil microbial quantity and diversity. Applied Soil Ecology, 119, 183-191.

Fernández-Bayo, J. D., Achmon, Y., Harrold, D. R., McCurry, D. G., Hernandez, K., Dahlquist-Willard, R. M., ... & Simmons, C. W. (2017). Assessment of two solid anaerobic digestate soil amendments for

effects on soil quality and biosolarization efficacy. Journal of agricultural and food chemistry, 65(17), 3434-3442.

Fernandez-Bayo, J. D., Randall, T. E., Achmon, Y., Hestmark, K., Harrold, D. R., Su, J., ... & Simmons, C. (2017). Effect of partially stabilized organic amendments on volatile acids production and pest inactivation using soil biosolarization. In 2017 ASABE Annual International Meeting (p. 1). American Society of Agricultural and Biological Engineers.

Fernandez-Bayo, J. D., Toniato, J., Simmons, B. A., & Simmons, C. W. (2017). Structure and activity of thermophilic methanogenic microbial communities exposed to quaternary ammonium sanitizer. Journal of Environmental Sciences, 56, 164-168.

Gordon, S. B., Buist, A. S., Hopewell, P., Pinkerton, K., Sly, P., West, T. E., ... & Adhikari, N. K. (2017). How Do We "Help the World Breathe"?. American journal of respiratory and critical care medicine, 196(9), 1100-1102.

Mitchell, D. C., Castro, J., Armitage, T. L., Vega-Arroyo, A. J., Moyce, S. C., Tancredi, D. J., ... & Schenker, M. B. (2017). Recruitment, methods and descriptive results of a physiologic assessment of latino farmworkers: the California heat illness prevention study (CHIPS). Journal of occupational and environmental medicine, 59(7), 649.

Moyce, S., Mitchell, D., Armitage, T., Tancredi, D., Joseph, J., & Schenker, M. (2017). Heat strain, volume depletion and kidney function in California agricultural workers. Occupational and environmental medicine, 74(6), 402-409.

Nelson D. August 31, 2017. Protecting California's Farmworkers as Temperatures Climb. Retrieved January 19, 2022, from https://www.ucdavis.edu/climate/news/protecting-californias-farmworkers-as-temperatures-climb

Oldfield, T.L., Achmon, Y., Perano, K.M., Dahlquist-Willard, R.M., VanderGheynst, J.S., Stapleton, J.J., Simmons, C.W. and Holden, N.M. (2017). A life cycle assessment of biosolarization as a valorization pathway for tomato pomace utilization in California. Journal of cleaner production, 141, 146-156.

Sun X, Wei H, Young DE, Bein KJ, Smiley-Jewell SM, Zhang Q, Fulgar CCB, Castañeda AR, Pham AK, Li W, Pinkerton KE. Differential pulmonary effects of wintertime California and China particulate matter in healthy young mice. Toxicology letters. 2017 August 15;278:1-8. PubMed PMID: 28698096; PubMed Central PMCID: PMC5572813

Schenker, M. "The Health of Immigrant Farm Workers." Lecture - UC Davis Campus Community Book Project. UCD, February 9, 2017.

Schenker, M. "The Substantial Contribution of Immigrant Workers to the History of Occupational Health." International Commission on Occupational Health. Occupational Conference, Gothenburg, Sweden, March 29-31, 2017.

Worley, J. N., Flores, K. A., Yang, X., Chase, J. A., Cao, G., Tang, S., ... & Atwill, E. R. (2017). Prevalence and genomic characterization of Escherichia coli O157: H7 in cow-calf herds throughout California. Applied and environmental microbiology, 83(16), e00734-17.

Yu, C., Harrold, D. R., Claypool, J. T., Simmons, B. A., Singer, S. W., Simmons, C. W., & VanderGheynst, J. S. (2017). Nitrogen amendment of green waste impacts microbial community, enzyme secretion and potential for lignocellulose decomposition. Process Biochemistry, 52, 214-222.

2016

Ahn KC, Ranganathan A, Bever CS, Hwang SH, Holland EB, Morisseau K, Pessah IN, Hammock BD, Gee SJ. Detection of the Antimicrobial Triclosan in Environmental Samples by Immunoassay. Environmental science & technology. 2016 April 5;50(7):3754-61. PubMed PMID: 26937944; PubMed Central PMCID: PMC4821808; DOI: 10.1021/acs.est.5b05357.

Antony, V. B., Redlich, C. A., Pinkerton, K. E., Balmes, J., & Harkema, J. R. (2016). National Institute of Environmental Health Sciences: 50 Years of Advancing Science and Improving Lung Health. American Journal of Respiratory and Critical Care Medicine, 194(10), 1190-1195.

Belafsky, P. C., Peake, J., Smiley-Jewell, S. M., Verma, S. P., Dworkin-Valenti, J., & Pinkerton, K. E. (2016). Soot and house dust mite allergen cause eosinophilic laryngitis in an animal model. The Laryngoscope, 126(1), 108-112.

Bever CS, Dong JX, Vasylieva N, Barnych B, Cui Y, Xu ZL, Hammock BD, Gee SJ. VHH antibodies: emerging reagents for the analysis of environmental chemicals. Analytical and bioanalytical chemistry. 2016 September;408(22):5985-6002. PubMed PMID: 27209591; PubMed Central PMCID: PMC4983233; DOI: 10.1007/s00216-016-9585-x.

Castañeda AR, Pinkerton KE. Investigating the Effects of Particulate Matter on House Dust Mite and Ovalbumin Allergic Airway Inflammation in Mice. Current protocols in toxicology. 2016 May 4;68:18.18.1-18.18.18. PubMed PMID: 27145110; PubMed Central PMCID: PMC4988128; DOI: 10.1002/cptx.5.

Fathallah, F. A., Tang, S. C., & Waters, T. (2016). Development and evaluation of ergonomic interventions for bucket handling on farms. Human factors, 58(5), 758-776.

Holguin, F., Schenker, MB In: Achieving Respiratory Health Equality: A United States Perspective. Migrant Health: Immigration and Nonoccupational Lung Diseases. Humana Press. 2016 Oct; 57-64.

Kurt OK, Zhang J, Pinkerton KE. Pulmonary health effects of air pollution. Current opinion in pulmonary medicine. 2016 March;22(2):138-43. PubMed PMID: 26761628; PubMed Central PMCID: PMC4776742; DOI: 10.1097/MCP.0000000000000248.

Leigh JP, Grosse SD, Cassady D, Melnikow J, Hertz-Picciotto I. Spending by California's Department of Developmental Services for Persons with Autism across Demographic and Expenditure Categories. PloS one. 2016 March 25;11(3): e0151970. PubMed PMID: 27015098; PubMed Central PMCID: PMC4807877.

Moyce, S., Joseph, J., Tancredi, D., Mitchell, D., & Schenker, M. (2016). Cumulative incidence of acute kidney injury in California's agricultural workers. Journal of occupational and environmental medicine, 58(4), 391-397.

Reid, A., & Schenker, M. B. (2016). Hired farmworkers in the US: Demographics, work organisation, and services. American journal of industrial medicine, 59(8), 644-655.

Schenker, M. "Occupational Health of Immigrant Workers." (Webinar) N273A Class Lecture, UCSF, Nov. 9, 2016.

Schenker, M. "Immigrant Worker Health Issues." OEH Interdisciplinary Grand Rounds, UC San Francisco, Sept. 22, 2016.

2015

Anderson, D. S., Patchin, E. S., Silva, R. M., Uyeminami, D. L., Sharmah, A., Guo, T., ... & Van Winkle, L. S. (2015). Influence of particle size on persistence and clearance of aerosolized silver nanoparticles in the rat lung. Toxicological Sciences, 144(2), 366-381.

Chung, Y. K., & Leigh, J. P. (2015). Medicaid use by documented and undocumented farm workers. Journal of Occupational and Environmental Medicine, 57(3), 329-333.

Du J, Leigh JP. Effects of wages on smoking decisions of current and past smokers. Annals of epidemiology. 2015 August;25(8):575-582.e1. PubMed PMID: 26066536; DOI:10.1016/j.annepidem.2015.03.016.

Plummer LE, Carosino CM, Bein KJ, Zhao Y, Willits N, Smiley-Jewell S, Wexler AS, Pinkerton KE. Pulmonary inflammatory effects of source-oriented particulate matter from California's San Joaquin Valley. Atmospheric environment (Oxford, England : 1994). 2015 October 1;119:174-181. PubMed PMID: 26568698; PubMed Central PMCID: PMC4639935; DOI: 10.1016/j.atmosenv.2015.08.043.

Leigh JP, Du J. Brief Report: Forecasting the Economic Burden of Autism in 2015 and 2025 in the United States. Journal of autism and developmental disorders. 2015 December;45(12):4135-9. PubMed PMID: 26183723.

Leigh JP, Du J. Brief Report: Forecasting the Economic Burden of Autism in 2015 and 2025 in the United States. Journal of autism and developmental disorders. 2015 December;45(12):4135-9. PubMed PMID: 26183723; DOI: 10.1007/s10803-015-2521-7.

Leigh JP, Markis CA, Iosif AM, Romano PS. California's nurse-to-patient ratio law and occupational injury. International archives of occupational and environmental health. 2015 May;88(4):477-84. PubMed PMID: 25216822.

Leigh JP, Markis CA, Iosif AM, Romano PS. Erratum to: California's nurse-to-patient ratio law and occupational injury. International archives of occupational and environmental health. 2015 May;88(4):485-6. PubMed PMID: **25585819;** DOI:10.1007/s00420-015-1017-2.

Leigh JP, Markis CA, Iosif AM, Romano PS. Erratum to: California's nurse-to[1]patient ratio law and occupational injury. International archives of occupational and environmental health. 2015 May;88(4):485-6. PubMed PMID: 25585819.

Leigh, J. P., & Medel-Herrero, A. (2015). Participation in the women, infants, and children (WIC) program as reported by documented and undocumented farm worker adults in the households. Journal of Agromedicine, 20(4), 409-418**.**

Leigh JP, Du J. Brief Report: Forecasting the Economic Burden of Autism in 2015 and 2025 in the United States. Journal of autism and developmental disorders. 2015 December;45(12):4135-9. PubMed PMID: 26183723.

Li, X., Xue, M., Raabe, O. G., Aaron, H. L., Eisen, E. A., Evans, J. E., ... & Pinkerton, K. E. (2015). Aerosol droplet delivery of mesoporous silica nanoparticles: A strategy for respiratory-based therapeutics. Nanomedicine: Nanotechnology, Biology and Medicine, 11(6), 1377-1385.

Linderholm, A. L., Franzi, L. M., Bein, K. J., Pinkerton, K. E., & Last, J. A. (2015). A quantitative comparison of intranasal and intratracheal administration of coarse PM in the mouse. Integrative pharmacology, toxicology and genotoxicology, 1(1), 5-10.

McCurdy, S. A., Stoecklin-Marois, M. T., Tancredi, D. J., Hennessy-Burt, T. E., & Schenker, M. B. (2015). Region of birth, sex, and reproductive health in rural immigrant Latino farmworkers: The MICASA study. The Journal of Rural Health, 31(2), 165-175.

Mitchell, D. C., Armitage, T. L., Schenker, M. B., Bennett, D. H., Tancredi, D. J., Langer, C. E., ... & Mitloehner, F. M. (2015). Particulate matter, endotoxin, and worker respiratory health on large Californian dairies. Journal of Occupational and Environmental Medicine, 57(1), 79-87.

O'Connor, K., Stoecklin-Marois, M., & Schenker, M. B. (2015). Examining nervios among immigrant male farmworkers in the MICASA study: sociodemographics, housing conditions and psychosocial factors. Journal of Immigrant and Minority Health, 17(1), 198-207.

Pinkerton, K. E., Harbaugh, M., Han, M. K., Jourdan Le Saux, C., Van Winkle, L. S., Martin, W. J., ... & George, M. (2015). Women and lung disease. Sex differences and global health disparities. American Journal of Respiratory and critical care Medicine, 192(1), 11-16.

Schenker, M. B., McCurdy, S. A., Riden, H. E., & Villarejo, D. (2015). Improving the health of agricultural workers and their families in California: current status and policy recommendations. Univ Calif Glob Heal Inst, 1-26.

Silva, R. M., Anderson, D. S., Franzi, L. M., Peake, J. L., Edwards, P. C., Van Winkle, L. S., & Pinkerton, K. E. (2015). Pulmonary effects of silver nanoparticle size, coating, and dose over time upon intratracheal instillation. Toxicological Sciences, 144(1), 151-162.

Stoecklin-Marois, M. T., Bigham, C. W., Bennett, D., Tancredi, D. J., & Schenker, M. B. (2015). Occupational exposures and migration factors associated with respiratory health in California Latino farm workers. Journal of occupational and environmental medicine, 57(2), 152-158.

Van Winkle, L. S., Bein, K., Anderson, D., Pinkerton, K. E., Tablin, F., Wilson, D., & Wexler, A. S. (2015). Biological dose response to PM2. 5: effect of particle extraction method on platelet and lung responses. Toxicological Sciences, 143(2), 349-359.

Xiao, H., Stoecklin-Marois, M., Li, C. S., McCurdy, S. A., & Schenker, M. (2015). Cohort study of physical activity and injury among Latino farm workers. American journal of industrial medicine, 58(7), 737-745.

C.2. Website(s) or other Internet site(s) – include URL(s)

Center website: https://aghealth.ucdavis.edu/
Facebook: https://www.facebook.com/AgHealthUCD
Twitter: https://twitter.com/AgHealthUCD
Instagram: https://www.instagram.com/aghealthucd/
YouTube: https://www.youtube.com/channel/UCCrF9GcijzIdd2shYwCFGjw

C.3. Technologies or techniques
Nothing to report.

C.4. Inventions, patent applications, and/or licenses
Nothing to report.

C.5. Other products and resource sharing

Wildfire and COVID-19 training materials have been shared extensively with all AFF Centers, NIOSH and disseminated extensively with advocacy groups.

D. PARTICIPANTS

D.1. What individuals have worked on the project? Please include calendar, academic, and summer months.
N/A

D.2 Personnel updates
N/A

E. IMPACT

E.1 - What is the impact on the development of human resources, if applicable?
Not applicable.

E.2 - What is the impact the Public Health Relevance and Impact? The investigator should address how the findings of the project relate beyond the immediate study to improved practices, prevention or intervention techniques, legislation, policy, or use of technology in public health.

Center studies have had a major impact by enhancing the awareness of heat illness, air pollution, and climate change among workers in agriculture. In addition, the impact of wildfires has led to widely disseminated guidelines on worker safety, as well as a checklist for employers to ensure heightened awareness of practices to be followed during periods of poor air quality with the transport of particles over large distances from the origin of wildfires.

F. CHANGES

F.1 – Changes in approach and reasons for change, including changes that have a significant impact on expenditures
N/A

F.2 - Actual or anticipated challenges or delays and actions or plans to resolve them
N/A

F.3 - Significant changes to human subjects, vertebrate animals, biohazards, and/or select agents
N/A

G. Special Reporting Requirements

G.1 Special Notice of Award Terms and Funding Opportunities Announcement Reporting Requirements
N/A

G.2 Responsible Conduct of Research
N/A

G.3 Mentor's Research Report or Sponsor Comments
N/A

G.4 Human Subjects

G.4.a Does the project involve human subjects?
Yes

G.4.b Inclusion Enrollment Data:
N/A
G.4.c ClinicalTrials.gov
Does this project include one or more applicable clinical trials that must be registered in ClinicalTrials.gov under FDAAA?
No

G.5 Human Subject Education Requirement
Are there personnel on this project who are newly involved in the design or conduct of human subject's research?
No

G.6 Human Embryonic Stem Cells (HESCS)
Does this project involve human embryonic stem cells (only hESC lines listed as approved in the NIH Registry may be used in NIH funded research)?
No

G.7 Vertebrate Animals
Does this project involve vertebrate animals?
Yes

G.8 Project/Performance Sites
University of California, Davis

G.9 Foreign Component
N/A

G.10 Estimated Unobligated Balance
G.10.a Is it anticipated that an estimated unobligated balance (including prior year carryover) will be greater than 25% of the current year's total approved budget?
N/A

G.11 Program Income
Is program income anticipated during the next budget period?
N/A

G.12 F&A Costs
Is there a change in performance sites that will affect F&A costs?
N/A

I. OUTCOMES

I. Provide a concise summary of the outcomes or findings of the award, written for the general public in clear and comprehensible language, without including any proprietary, confidential information or trade secrets

Note: project outcome information will be made public in NIH RePORTER

WCAHS has had a productive and effective six years of accomplishments with multiple center-wide initiatives as well as the funding of numerous programs supported through the Emerging Issues, Pilot, Outreach, and Rapid Response Programs. Highly successful programs in heat Illness, wildfire guidelines, and sexual harassment training were initiated during this period of time. WCAHS significantly expanded its communication efforts, utilizing a variety of styles and media to convey our activities and translate research findings. With institutional support from UC Davis, we funded graduate student researchers to advance their research related to agricultural health and safety.

WCAHS devoted considerable effort to respond to the COVID-19 pandemic in 2020 and 2021. WCAHS leadership contributed to a CDC working group to develop guidance for the agricultural industry, served on expert panels, and conducted trainings for farmers, agricultural employers, and farmworker-serving community organizations. WCAHS developed the first COVID-19 workplace prevention checklist and training guide for agriculture in the west. WCAHS resources have been widely distributed throughout the western region and have been adopted nationwide for clear and culturally tailored communication to Spanish-speaking farmworkers. Based on the success of WCAHS efforts supporting the agricultural industry and addressing COVID-19 hazard assessment, the State of California contracted with WCAHS to continue this work, which dramatically expanded the reach of WCAHS/NIOSH-funded work.

Western Center for Agricultural Health and Safety

Kent E. Pinkerton, Ph.D.

Planning and Evaluation Core: Administration, Evaluation, and Emerging Issues

B. ACCOMPLISHMENTS

B.1. What are the major goals of the project?

The Planning and Evaluation Core provides infrastructure to support strategic planning, overall administration, coordination, and communication among the cores, programs, and projects. This core ensures that both the internal Steering Committee and External Advisory Board meet regularly to evaluate WCAHS goals and progress. In addition, the Planning and Evaluation Core works to implement the results from research projects into educational material or outreach activities.

The Planning and Evaluation Core involves each of the members in a fundamental role in the fulfillment of the mission and advance towards the vision, achieving as a result the outstanding performance of the center. Thus, under this work philosophy based on commitment, creativity, and dynamism, the WCAHS administrative team, including the Director, Associate Director, Outreach Director, Research Director, and Center Manager meet weekly to review, prioritize, and advance center activities.

The Planning and Evaluation Core consists of three components: Administration, Evaluation, and Emerging Issues. The Administration unit and Emerging Issues Program are housed at the Center for Health and the Environment on the UC Davis campus, while Program Evaluation is at the Clinical and Translational Sciences Center (CTSC) on the UC Davis Health Systems campus in Sacramento. The Specific Aims of the Planning and Evaluation Core are to:

1. **Provide leadership, vision, and direction for all center cores, affiliates, and stakeholders through Center Administration.**

2. **Evaluate the impact of the center, its programs, and its research projects on improving health and safety in western agriculture through research, education, and outreach.**

3. **Identify and address new or emerging problems in western agricultural health and safety through an Emerging Issues Program.**

B.2. What did you accomplish under these goals?

The WCAHS Evaluation and Planning Core consists of three primary elements: Center Administration, Evaluation, and Emerging Issues. As such, each sub-core has separate activities and accomplishments, which are summarized below.

Center Administration Accomplishments

The planning sub-core provided leadership, vision, and direction for all center cores, affiliates, and stakeholders through center administration. The WCAHS Leadership Group met twice per month to review, prioritize, and advance center activities, as well as provide leadership in convening center faculty and stakeholders in research and advisory meetings.

Center-wide Events

To foster new research collaborations both within the center and throughout the western region (Arizona, California, Hawaii, and Nevada), the planning sub-core executed numerous workshops, seminars, and conferences from 2016 to 2021.

Cross-center Collaboration

Over the past six years, the WCAHS Evaluation and Planning Core served as a liaison to NIOSH, other centers, campus units, and agricultural health and safety-related agencies and organizations. WCAHS' Evaluation and Planning and Outreach Cores contributed to the Agriculture, Forestry, and Fishing's (AgFF) Evaluators, Coordinators, and Outreach Group (ECO), a cross-center forum that allows the AgFF centers to share program methods, expertise, and peer mentoring with new personnel. WCAHS participated in ECO conference calls, which featured training sessions on topics including promoting NIOSH agricultural centers' videos, altmetrics, and educational resources for agriculture. WCAHS also participated in cross-center initiatives, such as the annual National Farm Safety and Health Week and the NIOSH/CDC Beat the Heat summer campaign in 2017, specifically by contributing to YouTube videos, educational resources, and social media awareness.

Evaluation Accomplishments

The Evaluation Team, with the support of the Leadership Group and Center Administration, continued to provide the necessary infrastructure and activities to conduct a comprehensive evaluation, which has been integral to the center's continued success. Over the past six years, the WCAHS Evaluation Team conducted both process and outcomes evaluation and regularly shared the data with the Leadership Group to advance and strengthen the function and success of WCAHS. Examples of the evaluation activity and the utilization of data and related findings are described below.

Data and Tracking

At the beginning of the funding period, evaluators and WCAHS administrators met with the leaders of the outreach core and each research project to review the center logic model, identify evaluation questions, and determine required evaluation data and tracking needs. The logic model exercise proved to be a useful tool to align project activities and outputs with desired long-term outcomes, and to link those outcomes to the overall goals of the center.

Another important role of the Evaluation Team was to track activities, outputs, and outcomes of the center and associated projects. Tracking center outputs and outcomes was key to demonstrating the reach and impact of the center, as well as planning for future work. This included the tracking of publications, grants, media coverage, and presentations. Publications and grants associated with the center or a research project were routinely recorded based on lookups in SCOPUS (publications), NIH RePORTER (NIH grants), and the School of Medicine Office of Research grants database (external non-NIH grants). Data on honors and awards, accomplishments, scientific products, media coverage, presentations, and success stories were collected through annual progress reports, personal communication, and online searches. Final outputs and outcomes approved by WCAHS investigators were entered into a tracking system for reporting purposes. These data have been essential in demonstrating the outputs and outcomes of the center and its overall impact.

Evaluation support for Outreach, Pilot/Feasibility, and Emerging Issues

The Evaluation Team was instrumental in assessing the success of the center's grant programs in Outreach, Pilot/Feasibility, and Emerging Issues and describing the impact and return on investment for WCAHS-

funded research. The Evaluation Team worked closely with the Outreach Team in the previous grant period. An important accomplishment was the establishment of an outreach activity tracking database using the Qualtrics survey software platform. In addition to providing an efficient method for measuring outreach activity, the database was used to generate quarterly interactive maps to display WCAHS outreach in its geographic catchment. These maps displayed the number and type of outreach events, location of research sites, and geographic areas represented by key stakeholders. The Evaluation and Planning Core used the maps and data to identify gaps in WCAHS outreach as well as to prospectively and retrospectively evaluate the impact of specific outreach activities.

Additionally, evaluation of training approaches and curriculum was carried out to provide timely feedback for continuous improvement and further development. For example, in November 2019, the Evaluation Team analyzed data from sexual harassment prevention trainings arranged by the California Strawberry Commission. The training was conducted by WCAHS outreach specialists to 517 agricultural supervisors. A pre- and post-training session survey conducted by the Evaluation Team showed that participants increased their knowledge and awareness of sexual harassment prevention practices. Specifically, topics that covered sexual harassment definitions, examples of sexual harassment, and applicable laws showed the greatest change among participants, which demonstrated the objectives of the training were met.

A primary goal of the Pilot/Feasibility Program was to encourage the development of creative research and intervention projects while nurturing researchers new to investigating agricultural health and safety. In 2021, the Evaluation Team created an inventory checklist to examine project-related accomplishments of 48 Pilot/Feasibility grants awarded from 2016–2021. Results indicated that many grantees were successful in progressing and disseminating their work. A total of 15 publications and 110 presentations and a combined $2.1 million in subsequent grants were obtained by former Pilot/Feasibility recipients. Of those who had responded to a survey in Spring 2021, 36% of grantees noted they had formed new collaborations, 24% conducted outreach to communities of interest, and 12% disseminated their work through digital media (e.g., Twitter, YouTube, blogs, Facebook). These data informed the center on the opportunities to further support Pilot/Feasibility awardees in professional development, scientific communication, and dissemination of related work (see Pilot/Feasibility Program strategy for a description of a new monthly mentoring meeting series).

In addition to planned evaluation activities, the Evaluation Team played a significant role in WCAHS' response to emerging issues. For example, Dr. Rebeca Giacinto supported projects requiring special expertise in building capacity among community stakeholders, collecting and analyzing bilingual/bicultural qualitative data on topics, such as the impact of wildfires on agricultural workers (Riden et al. 2020a), and developing culturally and linguistically relevant pesticide safety education materials for farmworkers and employers in the northern and central California regions. In response to the COVID-19 pandemic, the Evaluation Team assisted with an employer survey in English and Spanish about adaptations made due to COVID-19 to identify concerns, needs, and general characteristics of those surveyed. These results were disseminated to agricultural employers, supervisors, farm labor contractors, agricultural researchers, and the community in the form of research briefs and journal publications. The Evaluation Team also developed tracking forms for community-based organizations and farmworker employers to record their COVID-19 outreach and educational activities. The Evaluation Team provided regular reports and data summaries of these activities for the center.

<u>Cross-center Collaboration</u>

From 2020 to 2021, the Evaluation Team collaborated with the Southeastern Coastal Center for Agricultural Health and Safety (Florida), the Pacific Northwest Agricultural Safety and Health Center (Washington), and the Southwest Center for Agricultural Health, Injury Prevention, and Education Center (Texas) on a contribution analysis (Downes et al. 2019) of the AgFF centers' role in addressing heat-related illness. After a year of intensive collaboration, a comprehensive logic model that summarized the four centers' heat-related illness outputs and outcomes was produced. The approach informed NIOSH on best practices and served as a model for other planned contribution analyses by NIOSH.

In addition to supporting the center-wide Program Performance One Pager with Center Administration, the Evaluation Team created a Program Performance One Pager in 2018 that outlines the priorities of the center, center activities and accomplishments, and next steps. This document was created in collaboration with NIOSH and is published on the NIOSH website. Center Administration and the Evaluation Team participated in other cross-center initiatives such as the National Farm Safety and Health Week, Mental Health Awareness Week, and NIOSH/CDC Beat the Heat summer campaign.

External Advisory Board and Center Events

Evaluation data were regularly shared with the WCAHS Leadership Group and External Advisory Board (EAB), as well as with the leaders of each project and the Outreach Team. In advance of EAB meetings, the Evaluation Team surveyed members to ask for ideas about potential emerging issues as well as consideration of center strengths and weaknesses. During the meeting, the board reviewed the survey results and gave additional recommendations. The Evaluation Team also collected feedback from attendees of center events such as the annual research symposium, monthly seminars, and open houses. Attendee feedback was tabulated for the Leadership Group to consider adjustments to future center activities and initiatives.

Emerging Issues Accomplishments

The Leadership Group, with input from the EAB and other WCAHS partners and investigators, identified emerging agricultural health and safety concerns to address. The Emerging Issues projects over the past six years included 1. sexual harassment in agriculture, 2. cannabis worker health and safety, 3. wildfire smoke exposure, and 4. COVID-19 in agriculture.

B.3. Competitive Revisions/Administrative Supplements

Year 6 – additional year of funding through NIOSH. See B2 for accomplishments associated with Year 6 activities.

B.4. What opportunities for training and professional development did the project provide?

The Emerging Issues Program allowed the center to offer grants to foster professional development and allow those funded to fulfill their professional and research goals. Specifically, the center funded four major projects: 1) sexual harassment in agriculture, 2) cannabis worker health and safety, 3) wildfire smoke exposure, and 4) COVID-19 in agriculture.

Issue 1: Sexual Harassment in Agriculture

Project Leads: Stephen McCurdy, M.D., M.P.H., Kimberly Prado, Ph.D., UC Davis

Studies on sexual harassment in agriculture have shown that up to 80% of women farmworkers in California's Central Valley have experienced some form of sexual harassment (Morales Waugh 2010).

WCAHS funded UC Davis researchers Dr. McCurdy and the graduate student Kimberly Prado to conduct research to examine sexual harassment in agriculture in California. The Emerging Issues Program provided $20,000 in 2016–2017 and continued to provide conference and research supply support through 2021. McCurdy and Prado obtained additional funding to extend their work to include a comparison with Mexican agricultural workers. The goal of the project was to understand attitudes, behaviors, and experiences around sexual harassment in the agricultural workplace to improve education and prevention practices. Outputs from the project include a journal article (Prado et al. 2021), conference presentations, an educational story, and a policy brief. Prado successfully completed her Ph.D. in Epidemiology in 2021 and now has a post-doctoral position at the University of Texas at Austin.

Issue 2: Cannabis Worker Health and Safety

Project Leads: Marc Schenker, M.D., M.P.H., Farzaneh Khorsandi, Ph.D., UC Davis

California legalized recreational marijuana use in 2016, facilitating an opportunity to characterize the cannabis worker population and identify unique occupational hazards experienced by cannabis workers. Drs. Schenker and Khorsandi were funded through the Emerging Issues Program in 2017 to identify key health and safety issues of the industry.

They visited numerous cannabis farms and greenhouses, conducted hazard assessments, and identified priority topics for worker surveys. In 2019, Dr. Schenker continued the work with additional Emerging Issues funds and enrolled 29 workers from two cannabis cultivation facilities. Participants were mostly white and Latino men under 30, with a median of 26 months of employment in the cannabis industry. Nasal, skin, and eye irritation were reported as well as respiratory symptoms including cough and wheeze. In 2021, Dr. Schenker convened a virtual meeting with the goal of bringing together cannabis industry occupational health and safety stakeholders to identify the most critically needed research, regulatory, and educational actions to prevent occupational illness and injury among cannabis workers. The meeting "Cannabis Industry: Setting Priorities for Occupational Health" was held on July 22, 2021 and was attended by 45 participants. An op-ed summarizing the needs identified during the presentations and focus groups is in preparation. Additional outputs from the project include a book chapter (Schenker et al. 2021), numerous presentations, including at EPICOH (Beckman et al. 2021), cannabis worker safety posters (see publication list), and additional funding ($144,949) from the State of California Bureau of Cannabis Control. A total of $85,000 in Emerging Issues funds were committed to cannabis worker health and safety between 2017 and 2021.

Issue 3: Wildfire Smoke Exposure

Project Leads: WCAHS Outreach Core; Laura Stock, M.P.H., UC Berkeley; Kathryn Conlon, Ph.D., UC Davis

On December 13, 2018, the Camp Fire became the deadliest and most costly wildfire in California history, blanketing Sacramento and much of the Central Valley in smoke. In response, members of the California Labor Federation, Worksafe, and the California Rural Legal Assistance Foundation submitted a request seeking emergency regulatory protection of outdoor workers from the harmful effects of wildfire smoke to the Occupational Safety and Health Standards Board. The emergency regulation, §5141.1 "Protection from Wildfire Smoke," was adopted on July 29, 2019 (CA DIR), and the WCAHS Outreach Core began working immediately to create a worksite checklist and employer training discussion guide and poster to help employers comply with the regulation (Figure 5). These resources were reviewed by Cal/OSHA and WCAHS Director (Pinkerton) for regulatory and scientific accuracy. Wildfire smoke exposure resources continue to be one of the most accessed webpages on the WCAHS' site, with 15,956 pageviews and 7,183 downloads (2018–2020). WCAHS wildfire resources have been linked to on the webpages and in the newsletters of other organizations a total of 98 times, including the Cal/OSHA wildfire resources page. To date, WCAHS has distributed over 10,000 wildfire smoke exposure training guides and posters to agricultural employers and 64,000 bilingual pocket cards describing when and how to use a respirator to farmworkers.

The WCAHS identified wildfire smoke as an important topic for agriculture and two proposals submitted to the Pilot/Feasibility Program in 2019 were funded as Emerging Issues projects. Dr. Conlon, Assistant Professor in the Department of Public Health Sciences and the School of Veterinary Medicine at UC Davis, was funded ($20,000) to systematically collect baseline data regarding farmworkers' and growers' knowledge, attitudes, and practices in response to the Cal/OSHA wildfire smoke emergency regulation, which went into effect on July 29, 2019. Conlon worked with WCAHS community partner organization, *Lideres Campesinas* to develop survey questions in Spanish to collect information that will be used to assess key factors influencing the implementation of the regulation. The project was delayed due to COVID-19 and next steps include pilot testing the survey, administering it, compiling data, analyzing data, and disseminating findings. Conlon presented the methodological approach for this project as part of the Agricultural Safety and Health Council of America's panel on "Protecting Agricultural Worker from Wildfire Related Concerns" on October 14, 2020. Conlon, WCAHS Director (Pinkerton), and WCAHS Program Manager (Riden) submitted a NIOSH R01 grant proposal in November 2019 related to wildfire smoke exposure and its health consequences among farmworkers. The proposal is being revised for resubmission.

The second Emerging Issues project funded ($30,000) in 2019 was led by Laura Stock, Director of the Labor Occupational Health Program at the University of California, Berkeley. The project team sought to explore agriculture workers' exposure to and experience with the California wine country wildfires in 2017 and 2019. Focus groups with 19 farmworkers and semi-structured interviews with eight representatives of community organizations in the Napa and Sonoma counties were conducted in April and May 2020. Farmworkers experience disadvantaged conditions before, during, and after wildfires due to language barriers, poverty, and immigration status, which put this population in a very vulnerable situation to face the multiple effects associated with wildfires. Findings from the focus groups and interviews found room for improvement in overall emergency preparedness and response, a clear need for mental health services to assist this population in managing stress, and studies to assess long-term exposures and document effects to better characterize impacts on worker health. Additionally, there is a need to consider paid leave programs for climate emergencies and training about workers' rights and health effects of wildfire smoke exposure in Spanish and Indigenous languages.

Issue 4: COVID-19 in Agriculture

Project Lead: Heather Riden, M.A., UC Davis; California Institute for Rural Studies

WCAHS initiated a multifaceted rapid response to COVID-19 beginning in March 2020. The WCAHS response included a comprehensive needs assessment, resource development, and farmer and employer data collection (Riden et al. 2020b). Feedback from the needs assessment indicated the need for agriculturally specific information on COVID-19, culturally and linguistically tailored information, and the desire for resources that provide brief and to-the-point instructions. WCAHS responded with a first-in-the nation worksite checklist and training guide on COVID-19 tailored for the agricultural industry. In addition to presenting in numerous webinars for farmers and agricultural employers across the west, WCAHS Director (Pinkerton) and Program Manager (Riden) served on the CDC working group to develop guidance for the agricultural industry. WCAHS rapidly developed and continues to maintain a robust website with up-to-date COVID-19 information. In collaboration with other universities and organizations, WCAHS developed a series of COVID-19 infographics for farmworkers and an infographic poster outlining best practices for increasing the effectiveness of cloth face coverings. All COVID-19 resources developed and disseminated by WCAHS are available in English and Spanish.

In addition to the dramatic impact COVID-19 was having on farmers and agricultural employers, WCAHS community-based organization partners raised concern about the impact on workers. In April 2020, Riden joined a network of organizations and researchers to create the COVID-19 Farmworker Study, led by the California Institute for Rural Studies (CIRS). WCAHS provided $65,000 between 2020 and 2021 in Emerging Issues funding to CIRS to launch a representative survey of California farmworkers. The WCAHS funding was leveraged by CIRS to obtain an additional $1,065,000 in funding from The California Endowment, Sierra Health Foundation, 11th Hour Project, and San Joaquin Valley Health Fund, and The California Wellness Foundation. Results of the survey found dramatic impacts on the livelihood of farmworkers (COFS 2021). Study results were disseminated through more than 50 media pieces, 30 presentations, and six reports. The collaboration established by the CIRS-led study was further expanded in a state-wide outreach and training effort led by Riden.

In October 2020, the WCAHS Program Manager secured $4,927,264 in funding from the California Labor and Workforce Development Agency (LWDA) for the COVID-19 Statewide Agriculture and Farmworker Education (SAFE) program, part of a statewide rapid response to COVID-19 from October 15, 2020 through June 30, 2022. WCAHS collaborated with the UC Davis College of Agricultural and Environmental Sciences Communications Team and a network of community-based organizations and agricultural industry groups to provide workers, growers, farm labor contractors, and community groups the training and safety information to reduce their risk of contracting COVID-19.

B.5. How did you disseminate the results to communities of interest?

Results from the center's core projects and Emerging Issues projects were disseminated via peer-reviewed publications, conference presentations, and abundant media coverage.

Media Coverage:

Aarons J. September 16, 2021. In-depth: Wildfire smoke presents danger to pregnant women, unborn babies. Retrieved January 7, 2022, from https://www.10news.com/news/in-depth/in-depth-wildfire-smoke-presents-danger-to-pregnant-women-unborn-babies

Abrams L. September 26, 2017. Davis Researchers Consider Health Risks Of Firefighting Chemicals, Pesticides. Retrieved January 6, 2022, from https://sacramento.cbslocal.com/2017/09/26/wildfire-smoke-pesticides/

Anderson C. November 24, 2018. Wildfire smoke can hurt your body in ways you never dreamed of. Retrieved January 6, 2020, from https://www.vcstar.com/story/news/2018/11/24/wildfire-smoke-can-hurt-your-body-ways-you-never-dreamed/2090002002/

Anderson C. November 19, 2018. Fine particles from wildfire smoke can hurt your body in ways you never dreamed of. Retrieved January 6, 2022, from https://www.sacbee.com/news/california/fires/article221795980.html

Anderson C, Glover M. October 11, 2017. Shut those windows. Fire smoke makes Northern California's air dangerous to breathe. Retrieved January 6, 2020, from http://www.sacbee.com/news/local/environment/article178229271.html

Antonios C. May 5, 2021. Cómo los agricultores tuvieron que eludir los programas estatales y del condado para vacunar a los trabajadores agrícolas. Retrieved January 7, 2022, from https://calmatters.org/calmatters-en-espanol/2021/05/agricultores-vacunan-trabajadores-agricolas/

Atkin E. November 21, 2018. Wildfire Smoke Could Shorten Californian Lifespans. Retrieved January 6, 2020, from https://newrepublic.com/article/152340/wildfire-smoke-shorten-californian-lifespans

Baragona S. Wildfire Smoke a Growing Health Problem. Retrieved January 6, 2020, from https://www.voanews.com/a/science-health_wildfire-smoke-growing-health-problem/6196037.html

Bernstein S. March 13, 2019. As wildfires devour communities, toxic threats emerge. Retrieved January 6, 2020, from https://www.reuters.com/article/us-california-wildfires-environment-feat-idUKKBN1QU17Z

Bernstein S. March 13, 2019. California Wildfires Left Toxic Threats Behind. Retrieved January 6, 2020, from https://www.claimsjournal.com/news/west/2019/03/13/289750.htm

Beaumont H. November 29, 2021. How toxic wildfire smoke affects pregnant people. Retrieved January 7, 2022, from https://www.ehn.org/wildfire-smoke-births-2655744649.html

Booth E. May 6, 2021. UC Davis panel talks about farmworkers during the pandemic. Retrieved January 7, 2022, from https://www.davisenterprise.com/news/local/uc-davis-panel-talks-about-farmworkers-during-the-pandemic/

Bojorouez K. September 28, 2021. 'Exposed to toxic smoke and ash': Proposed law would increase workplace protections amid wildfires. Retrieved January 7, 2022, from https://amp.fresnobee.com/article253712098.html

Brown A. In California's Wine County, Undocumented Grape Pickers Forced to Work in Fire Evacuation Zones. Retrieved January 6, 2020, from https://theintercept.com/2020/09/06/california-fires-undocumented-farm-workers/

Burdick G. September 9, 2021. Farmworkers Face Heat Risk Despite Regulations. Retrieved January 7, 2022, from https://ehsdailyadvisor.blr.com/2021/09/farmworkers-face-heat-risk-despite-regulations/

Campos M. July 26, 2021. UC Davis launches a $3 million project for farmworkers. Retrieved January 7, 2022, from https://theaggie.org/2021/04/05/uc-davis-launches-a-3-million-project-for-farmworkers/

City of West Sacramento. April 9, 2020. 4/09/20 Update: Stay Home for Easter. Retrieved January 6, 2020, from https://www.cityofwestsacramento.org/Home/Components/News/News/1635/67

Escalante E. February 2, 2021. COVID-19: Why UC Davis is launching a farmworker safety project before harvest ramp up. Retrieved January 7, 2022, from https://www.abc10.com/article/news/health/coronavirus/uc-davis-farmworker-project/103-f3fd436a-54b5-4622-98ca-d3572d6c4719

Ethnic Media Services. February 7, 2021. Essential but Disposable: How California Farmworkers Battle COVID-19. Retrieved January 7, 2022, from https://siliconeer.com/current/essential-but-disposable-how-california-farmworkers-battle-covid-19/

Fell A. October 11, 2021. What Is the Health Impact of Wildfire Smoke? Retrieved January 7, 2022, from https://magazine.ucdavis.edu/what-is-the-health-impact-of-wildfire-smoke/

Fruen L. April 29, 2020. Rural America braces to become the next coronavirus epicenter because of outbreaks at factories and food processing plants. Retrieved January 6, 2020, from https://www.dailymail.co.uk/news/article-8270337/Rural-America-braces-coronavirus-epicenter.html

Garcia A. May 3, 2020. Essential farmworkers risk COVID-19 exposure to maintain food supply. Retrieved January 6, 2020, from https://abcnews.go.com/Business/essential-farmworkers-risk-covid-19-exposure-maintain-food/story?id=70365950

Garcia E. May 15, 2021. Breaking barriers to COVID-19 care. Breaking barriers to COVID-19 care. Retrieved January 7, 2022, from https://www.dailydemocrat.com/2021/05/15/breaking-barriers-to-covid-19-care/

Garcia-Navarro L. November 18, 2018. Wildfires And Public Health Concerns. Retrieved January 6, 2020, from https://www.wkms.org/2018-11-18/wildfires-and-public-health-concerns#stream/0

German B. July 16, 2020. Emphasizing Importance of Coronavirus Safety Standards to Employees. Retrieved January 6, 2020, from https://agnetwest.com/emphasizing-importance-of-coronavirus-safety-standards-to-employees/

Green Queen Team. April 14, 2020. 'Essential' But Unprotected, Farmworkers Live In Fear Of Covid-19 But Keep Working. Retrieved January 6, 2020, from https://www.greenqueen.com.hk/essential-but-unprotected-farmworkers-live-in-fear-of-covid-19-but-keep-working-inside-climate-news/

Hammerich T. May 3, 2020. COVID-19 Workplace Safety. Retrieved January 7, 2022, from https://www.aginfo.net/report/48847/California-Ag-Today/COVID-19-Workplace-Safety

Hammerich T. June 5, 2020. Farm Labor Resources for COVID-19. Retrieved January 6, 2020, from https://www.aginfo.net/report/46167/California-Ag-Today/Farm-Labor-Resources-for-COVID-19

Hammerich T. May 26, 2020. Ag Health & Safety During COVID-19. Retrieved January 6, 2020, from https://www.aginfo.net/report/46071/California-Ag-Today/Ag-Health-Safety-During-COVID-19

Healy M. March 21, 2020. Why is the coronavirus so much more deadly for men than for women? Retrieved January 6, 2020, from https://www.latimes.com/science/story/2020-03-21/why-is-the-coronavirus-more-deadly-for-men-than-for-women

Hernandez L. April 7, 2021. Heat, Smoke, Pandemic: Dangers Multiply for Farmworkers in 2020. Retrieved January 7, 2022, from https://johnmuir.ucdavis.edu/news/heat-smoke-pandemic-dangers-multiply-farmworkers-2020

Hiro B. February 24, 2021. Professor Leads Study of Pandemic's Effect on Farmworkers. Retrieved January 7, 2022, from https://news.csusm.edu/professor-leads-study-of-pandemics-effect-on-farmworkers/

Hooker B. January 28, 2021. State contracts with UC Davis for COVID-19 farmworker training. Retrieved January 7, 2022, from https://www.agri-pulse.com/articles/15235-state-contracts-with-uc-davis-for-covid-19-farmworker-training

Hodgson M. October 6, 2020. Study documents COVID-19 impacts on farmworkers. Retrieved January 7, 2022, from https://santamariatimes.com/business/agriculture/study-documents-covid-19-impacts-on-farmworkers/article_2d3b22e8-e6dc-53fb-9af8-c90ef7c40949.html

Hooker B. July 15, 2020. Farmworkers, growers grapple with need for more COVID-19 tests and other resources. Retrieved January 6, 2020, from https://www.agri-pulse.com/articles/14065-farmworkers-growers-grapple-with-need-for-more-covid-19-tests-and-other-resources

Humboldt State Now. November 20, 2017. Workplace Safety in the Cannabis Industry. Retrieved January 6, 2022, from http://now.humboldt.edu/news/workplace-safety-in-the-cannabis-industry-the-subject-of-upcoming-presentat/

Judson A. August 31, 2021. Scientists concerned about Californians breathing burned plastic particles from wildfire smoke. Retrieved January 7, 2022 from https://www.abc10.com/article/news/local/wildfire/scientists-concerned-californians-breathing-smoke/103-bd8f2de2-1cde-4e92-9ae1-6b7e54e48556

Kan-Rice P. November 22, 2020. UC ANR Scientists Receive State Cannabis Research Grants. Retrieved January 7, 2022 from https://goldrushcam.com/sierrasuntimes/index.php/news/local-news/26732-uc-anr-scientists-receive-state-cannabis-research-grants

Kan-Rice P. June 12, 2020. UC Launches COVID-19 Prevention Survey on Farms. Retrieved January 6, 2022, from https://californiaagtoday.com/uc-launches-covid-19-prevention-survey-farms/

Kan-Rice P. June 12, 2020. UC conducts survey of COVID-19 prevention on farms. Retrieved January 6, 2022, from https://www.farmprogress.com/farm-operations/uc-conducts-survey-covid-19-prevention-farms

Kelly L. November 25, 2018. California wildfire toxic smoke may cause long-term health effects. Retrieved January 6, 2022, from https://www.washingtontimes.com/news/2018/nov/25/california-wildfire-toxic-smoke-may-cause-long-ter/

Kerber K. August 28, 2020. Does my COVID mask protect me from wildfire smoke? Experts answer key questions. Retrieved January 6, 2022, from https://www.sacbee.com/article245311900.html

Kerlin K. July 20, 2021. Wildfire, Smoke and Air Quality Experts. Retrieved January 6, 2022, from https://www.ucdavis.edu/climate/news/climate-change-experts-wildfire-smoke-and-air-quality

Klearman S. October 7, 2020. With harvest amid fire and smoke, how should Napa Valley protect its farmworkers? Retrieved January 7, 2022, from https://napavalleyregister.com/news/local/with-harvest-amid-fire-and-smoke-how-should-napa-valley-protect-its-farmworkers/article_d2b1cf42-d171-5364-a4b7-8efbdc13f9e7.html

Klobas R. September 29, 2020. Disruption of lives from the coronavirus disrupts Napa Valley agriculture. Retrieved January 7, 2022, from https://www.northbaybusinessjournal.com/article/article/disruption-of-lives-from-the-coronavirus-disrupts-napa-valley-agriculture/?ref=recent

Lanspa M. December 2017. Lung Health in the California Wildfires. Retrieved January 6, 2022, from https://www.thoracic.org/about/ats-podcasts/lung-health-in-the-california-wildfires.php

Li Y. June 4, 2020. Insufficient COVID-19 testing for U.S. public contributes to high death toll, says expert. Retrieved January 6, 2022, from http://www.ecns.cn/news/society/2020-06-04/detail-ifzwzeax1200686.shtml

Lopez N. September 28, 2021. California farmworkers face risks from heat, smoke. Regulations offer little protection. Retrieved January 7, 2022, from https://www.fresnobee.com/news/local/article253582334.html

Migrant Clinicians Network. August 14, 2020. Five on Friday: Farmworkers Vulnerable to the Virus. Retrieved January 6, 2022, from https://www.migrantclinician.org/blog/2020/aug/five-friday-farmworkers-vulnerable-virus.html

Miller C. August 26, 2020. California Wildfires Increases Misery for Growers. Retrieved January 6, 2022, from https://www.growingproduce.com/vegetables/california-wildfires-increases-misery-for-growers/

Nelson D. March 12, 2021. California expands access to COVID-19 testing to help communities open safely. Retrieved January 7, 2022, from https://www.dailydemocrat.com/2021/03/12/california-expands-access-to-covid-19-testing-to-help-communities-open-safely/

Neuffer C. November 2, 2020. UC Davis webinar discusses affects, dangers of wildfire smoke. Retrieved January 7, 2022, from https://www.tahoedailytribune.com/news/uc-davis-webinar-discusses-affects-dangers-of-wildfire-smoke/

Neurman E. October 13, 2020. Klamath COVID-19 outbreak shows risks to farmworkers. Retrieved January 7, 2022, from https://www.opb.org/article/2020/10/13/klamath-covid-19-outbreak-shows-risks-to-farmworkers/

Osgood B. July 15, 2021. 'What choice do we have?' US farm workers battle deadly heatwave. Retrieved January 7, 2022, from https://www.aljazeera.com/economy/2021/7/15/what-choice-do-we-have-us-farm-workers-battle-deadly-heat-wave#:~:text=do%20we%20have%3F-,'%20US%20farm%20workers%20battle%20deadly%20heatwave,their%20wages%20and%20their%20health.

Parshley L. April 28, 2020. Where the coronavirus is hitting rural America hard. Retrieved January 6, 2022, from https://www.vox.com/2020/4/28/21239536/coronavirus-georgia-south-dakota-missouri-nebraska-rural-america

Pourkish H, Sandoval S. March 4, 2021. UC Davis Launches Program to Keep Farm-workers Safe. Retrieved January 7, 2022, from https://spectrumnews1.com/ca/la-west/coronavirus/2021/03/04/uc-davis-launches-program-to-keep-farmworkers-safe

Ravikumar V. September 1, 2021. Strike team fighting Caldor Fire pulled because of COVID outbreak, prompting warning. Retrieved January 7, 2022, from https://www.charlotteobserver.com/news/nation-world/national/article253924928.html

Rodriguez D. October 30, 2021. Farm worker study exposes hardships during COVID-19 pandemic. Retrieved January 7, 2022, from https://www.thecalifornian.com/story/news/2021/10/30/invisible-no-more-indigenous-farmworkers-hardships-amplified-amid-pandemic-california-cofs-study-19/6140571001/

Rosenbaum M. September 21, 2020. Unhealthy air conditions due to wildfires may cause long-term health effects. Retrieved January 6, 2022, from https://theaggie.org/2020/09/21/unhealthy-air-conditions-due-to-wildfires-may-cause-long-term-health-effects/

Rosenbaum M. August 20, 2021. How California's toxic wildfire smoke affects your health. What the experts are saying. Retrieved January 7, 2022, from https://www.sacbee.com/news/california/fires/article253619218.html

Seda C. Masks for Fires: Kathryn Conlon, PhD, MPH Analyses new California Emergency Wildfire Smoke Regulation For Outdoor Workers. Retrieved January 6, 2022, from https://www.migrantclinician.org/blog/2019/sep/masks-fires-kathryn-conlon-phd-mph-analyses-new-california-emergency-wildfire-smoke-re

Silva-Benham J. February 10, 2021. Push to vaccinate Yolo ag workers. Retrieved January 7, 2022, from https://www.dailydemocrat.com/2021/02/10/push-to-vaccinate-yolo-ag-workers/

Tan J. April 2, 2020. Spotlight: Experts say COVID-19 mitigation efforts may reduce projected deaths in U.S. Retrieved January 7, 2020, from http://www.xinhuanet.com/english/2020-04/02/c_138941209.htm

Taylor D. September 19, 2019. Monterey scientist a leader in new wildfire research. Retrieved January 6, 2022, from https://www.montereyherald.com/2019/09/19/monterey-scientist-a-leader-in-new-wildfire-research/

TeSelle M. August 6, 2018. Smoky skies, bad air quality persist in NorCal another day. Retrieved January 6, 2022, from https://www.kcra.com/article/smoky-bad-air-quality-persists-for-another-day/22651900#

The Coastal News Group. February 8, 2021. Who's News: 2/12/21. Retrieved January 7, 2020, from https://thecoastnews.com/whos-news-2-12-21/

Townsend M. August 6, 2021. Significant health effects': UC Davis biologist warns residents sifting through burnt homes to wear N95 masks. Retrieved January 7, 2020, from https://fox40.com/news/california-connection/restoring-areas-damaged-by-wildfires-could-take-years/

Tuchinsky E. November 21, 2018. Lingering effects: Camp Fire harms health in myriad ways. Retrieved January 6, 2020, from https://www.newsreview.com/chico/content/lingering-effects/27378934/

Utzman M. September 30, 2020. Farmworkers face unique challenges in a global pandemic. Retrieved January 7, 2020, from https://psuvanguard.com/farmworkers-face-unique-challenges-in-a-global-pandemic/

Veeraiah A., Winters E. September 24, 2020. As Creek Fire become the largest in California history, farmworkers continue to labor without protection from smoke. Retrieved January 6, 2020, from https://www.wsws.org/en/articles/2020/09/24/fire-s24.html

Winters Express. April 16, 2020. COVID-19 resources for the agricultural community. Retrieved January 7, 2020, from https://www.wintersexpress.com/local-news/covid-19-resources-for-the-agricultural-community

Witt D. July 16, 2020. CDFA flyers educate farmers, workers on virus. Retrieved January 6, 2020, from https://www.lodinews.com/business/article_f0f2709a-c726-11ea-9a80-0f2045444d3d.html

Wong M. March 9, 2021. COVID-19 Statewide Agriculture and Farmworker Education Program strives to protect and educate the agricultural community during the pandemic. Retrieved January 7, 2020, from https://theaggie.org/2021/03/09/covid-19-statewide-agriculture-and-farmworker-education-program-strives-to-protect-and-educate-the-agricultural-community-during-the-pandemic/

Xinhua. March 25, 2020. Experts on why younger adults comprise big portion of U.S. COVID-19 cases. Retrieved January 7, 2020, from https://www.newtimes.co.rw/news/experts-why-younger-adults-comprise-big-portion-us-covid-19-cases

B.6 - What do you plan to do during the next reporting period to accomplish the goals?
N.A.

C. PRODUCTS

C.1. Publications, conference papers, and presentations

Peer-reviewed Publications

Fenske RA, Pinkerton KE. 2021. Climate Change and the Amplification of Agricultural Worker Health Risks. Journal of Agromedicine, 26(1), 15-17. https://doi.org/10.1080/1059924X.2021.1849211

Lu X, Zhang L, Du H, Zhang J, Li YY, Qu J, Zhang W, Wang Y, Bao S, Li Y, Wu C, Liu H, Liu D, Shao J, Peng X, Yang Y, Liu Z, Xiang Y, Zhang F, Silva RM, Pinkerton KE, Shen K, Xiao H, Xu S, Wong GWK; Chinese Pediatric Novel Coronavirus Study Team. 2020. SARS-CoV-2 Infection in Children. New England Journal of Medicine. doi: 10.1056/NEJMc2005073. [Epub ahead of print] PMID:32187458

Prado KY, Rivera-Heredia ME, Martínez-Servín LG, Guzmán-Carillo KY, McCurdy SA. 2021. “It’s wrong because it could be my sister, wife, or mother”: Workplace sexual harassment among men and women farmworkers in USA and Mexico. Journal of Agromedicine, 26(2): 220-230. doi: 10.1080/1059924X.2020.1825245

Prado KY, Rivera-Heredia ME, McCurdy SA. 2021. Exposure to workplace sexual harassment among women and men farmworkers in USA and Mexico. Journal of agricultural safety and health. doi: 10.13031/jash.14514

Reid A, Ronda-Perez E, Schenker MB. 2021. Migrant workers, essential work, and COVID-19. 2021. American Journal of Industrial Medicine, 64(2):73-7. https://doi.org/10.1002/ajim.23209

Riden HE, Felt E, Pinkerton KE. 2021. The Impact of Climate Change and Extreme Weather Conditions on Agricultural Health and Safety in California. In: Pinkerton KE, Rom WN (eds) Climate Change and Global Public Health. Respiratory Medicine, Humana, Cham. https://doi.org/10.1007/978-3-030-54746-2_16

Riden HE, Giacinto R, Wadsworth G, Rainwater J, Andrews T, Pinkerton KE. 2020. Wildfire smoke exposure: awareness and safety responses in the agricultural workplace. Journal of Agromedicine, 2;25(3):330-8. https://doi.org/10.1007/978-3-030-54746-2_16

Riden HE, Schilli K, Pinkerton KE. 2020. Rapid response to COVID-19 in agriculture: a model for future crises. Journal of Agromedicine, 25(4), 392-395. https://doi.org/10.1080/1059924X.2020.1815618

Schenker MB, Langer CE. 2021. Health and Safety of Cannabis Workers. In The Routledge Handbook of Post-Prohibition Cannabis Research (pp. 135-143). Routledge.

Willson BE, Gee NA, Willits NH, Li L, Zhang Q, Pinkerton KE, Lasley BL. 2021. Effects of the 2018 Camp Fire on birth outcomes in non-human primates: Case-control study. Reproductive Toxicology. 105:128-35. https://doi.org/10.1016/j.reprotox.2021.08.005

Xiao Y, Yan L, Zhang M, Pinkerton KE, Cao H, Xiao Y, Li W, Li S, Wang Y, Li S, Cao Z, Wong G, Xu H, Hang HT. 2020. Machine learning discovery of distinguishing laboratory features for severity classification of COVID-19 patients. IET Cyber-Systems and Robotics, 3:31–43. https://doi.org/10.1049/csy2.12005

C.2. Website(s) or other Internet site(s) – include URL(s)

Center website: https://aghealth.ucdavis.edu/
Facebook: https://www.facebook.com/AgHealthUCD
Twitter: https://twitter.com/AgHealthUCD
Instagram: https://www.instagram.com/aghealthucd/
YouTube: https://www.youtube.com/channel/UCCrF9GcijzIdd2shYwCFGjw

C.3. Technologies or techniques
N.A.

C.4. Inventions, patent applications, and/or licenses
N.A.

C.5. Other products and resource sharing

Print Resources

Beckman SF and Schilli K. December 18, 2020. Cannabis Workplace Safety Poster (1): Ergonomics Hazards, “Prevent Injuries at Work.”
https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/Ergonomic%20Hazards%20Flyer_v2_12.18.2020.pdf

Beckman SF and Schilli K. December 18, 2020. Cannabis Workplace Safety Poster (2): Respiratory and Dermal Hazards, “Know Your Risks at Work.”
https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/Respiratory%20and%20Dermal%20Hazards%20Flyer_v2_12.18.2020.pdf

Western Center for Agricultural Health and Safety. October 8, 2019. Wildfire Smoke Worksite Checklist. https://aghealth.ucdavis.edu/wildfires

Western Center for Agricultural Health and Safety. October 8, 2019. Wildfire Smoke Employer Training Discussion Guide and Poster. https://aghealth.ucdavis.edu/wildfires

D. PARTICIPANTS

D.1. What individuals have worked on the project? Please include calendar, academic, and summer months.

Commons ID	S/K	Name	Degrees(s)	Role	Cal	Aca	Sum	Foreign	Country	SS
		Andrews, Teresa		PRG REPR 3	1.19					
		Barber, McKenzie R.		STDT 3	0.20					
		Chong, Graciela M.		Admin Officer 2	0.06					
		Escobar de Carranza, Claudia P		Project Policy Analyst	1.61					
		Fathallah, Fadi A		RES-FY-B/E/E	0.99					
		Felt, Emily		ANL 2	7.25					
		Fernandez Bayo, Jesus Dionisio		Assistant Researcher	0.47					
		Francis, Hanna U		Student 3	0.14					
		Hall, Sandra E		EVENTS SPEC 3	0.36					
		Gaa, Megan Elise		Lab Assistant 3	0.56					
		Georgian, Elizabeth M		Editor	1.63					
		Hunter, Savannah M.		GSR	1.10					
		Jose, Keith L		INFO SYS ANL 3, INFO SYS SUPV 2, PROGR 6 SUPV	2.75					
		Kim, Han Seol H.		Student 3	1.02					

		Ledesma, Yahele		Student 3	1.58					
		Li, Xunde		Associate Researcher	0.17					
		Lieb, Heather Casey		GSR	1.51					
		Medel-Jerrero, Alvaro		ASST PROJ SCIENTIST-FY	2.90					
		Olivares, Leslie V		GSR, JR. Specialist, Community Education Specialist 3	4.48					
		Padilla, Destina A		Student 4	1.80					
		Phillips, Karen A.		Student 3	3.46					
		Pinkerton, Kent E.		Professor	1.77					
		Ramirez Sigala, Yajaira		Jr. Specialist	2.28					
		Riden, Heather E.		Academic Program Management Officer	39.84					
		Schilli, Kara M.		Community Specialist 3	1.19					
		Silva, Rona		Writer Editor 3.	0.12					
		Silva-Mora, Rigoberto		Blank Assistant 2/Community Education Specialist 2	1.09					
		Smiley-Jewell, Suzette M.		EDITOR PRN	1.13					
		Stevenson, Delaney		Student 3	0.20					
		Uyeminami, Dale Lee		SRA 3	0.56					
		Wu, Ching-Wen		Assistant Specialist	0.16					
		Zmich, Krysta L.		Jr. Specialist	0.77					

D.2 Personnel updates

N.A.

E. IMPACT

E.1 - What is the impact on the development of human resources, if applicable?
N.A.

E.2 - What is the impact the Public Health Relevance and Impact? The investigator should address how the findings of the project relate beyond the immediate study to improved practices, prevention or intervention techniques, legislation, policy, or use of technology in public health.

The Evaluation and Planning Core provided leadership, vision, direction, and evaluation for all center cores, affiliates, and stakeholders.

F. CHANGES

F.1 – Changes in approach and reasons for change, including changes that have a significant impact on expenditures
N.A.

F.2 - Actual or anticipated challenges or delays and actions or plans to resolve them

N.A.

F.3 - Significant changes to human subjects, vertebrate animals, biohazards, and/or select agents
N.A.

G. Special Reporting Requirements

G.1 Special Notice of Award Terms and Funding Opportunities Announcement Reporting Requirements
N.A.

G.2 Responsible Conduct of Research
N.A.

G.3 Mentor's Research Report or Sponsor Comments
N.A.

G.4 Human Subjects
G.4.a Does the project involve human subjects?
N.A.

G.4.b Inclusion Enrollment Data
N.A.

G.4.c ClinicalTrials.gov

Does this project include one or more applicable clinical trials that must be registered in ClinicalTrials.gov under FDAAA?
No

G.5 Human Subject Education Requirement
Are there personnel on this project who are newly involved in the design or conduct of human subject's research?
N.A.

G.6 Human Embryonic Stem Cells (HESCS)
Does this project involve human embryonic stem cells (only hESC lines listed as approved in the NIH Registry may be used in NIH funded research)?
No

G.7 Vertebrate Animals
Does this project involve vertebrate animals?

G.8 Project/Performance Sites
University of California, Davis

G.9 Foreign Component
N/A

G.10 Estimated Unobligated Balance
G.10.a Is it anticipated that an estimated unobligated balance (including prior year carryover) will be greater than 25% of the current year's total approved budget?
N.A.

G.11 Program Income
Is program income anticipated during the next budget period?
No

G.12 F&A Costs
Is there a change in performance sites that will affect F&A costs?
N.A.

I. OUTCOMES

I. Provide a concise summary of the outcomes or findings of the award, written for the general public in clear and comprehensible language, without including any proprietary, confidential information or trade secrets

Note: project outcome information will be made public in NIH RePORTER

The Evaluation and Planning Core provided leadership, vision, and direction for all center cores, affiliates, and stakeholders through center administration. The WCAHS Leadership Group met twice per month to review, prioritize, and advance center activities, as well as provide leadership in convening center faculty and stakeholders in research and advisory meetings.

The Evaluation Team, with the support of the Leadership Group and Center Administration, continued to provide the necessary infrastructure and activities to conduct a comprehensive evaluation, which has been integral to the center's continued success. Over the past six years, the WCAHS Evaluation Team conducted

both process and outcomes evaluation and regularly shared the data with the Leadership Group to advance and strengthen the function and success of WCAHS.

The Leadership Group, with input from WCAHS partners and investigators, identified emerging agricultural health and safety concerns to address. The Emerging Issues projects over the past six years included 1. sexual harassment in agriculture, 2. cannabis worker health and safety, 3. wildfire smoke exposure, and 4. COVID-19 in agriculture.

Western Center for Agricultural Health and Safety

Christopher W. Simmons, Ph.D.

Outreach Core: R2P, Education, and Outreach

B. ACCOMPLISHMENTS

B.1. What are the major goals of the project?

The Western Center for Agricultural Health and Safety (WCAHS) is a leader in advancing health and safety in the agricultural community. The center is unique in the breadth and depth of its reach and activities, with an especially strong focus on historically underserved groups including immigrant farmworkers and their families. The Outreach Core Program is an essential component of WCAHS' integrated approach to the creation and implementation of evidence-based approaches to important health and safety problems in the agricultural community. The Outreach Core's role is two-fold: first, to foster communication among and between WCAHS investigators and agricultural stakeholders to maximize the quality and practical utility of our research; and second, to promote the transfer of research findings and policy recommendations into the agricultural community (Research to Practice, "R2P"). Our efforts involve partnership with a diverse range of agricultural stakeholders and utilize the full spectrum of traditional and modern communications tools. The ultimate goal is to improve occupational health and safety in agriculture, particularly in the western region, and nationally as well.

The specific aims for the Outreach Core component of this proposal are:

Specific Aim # 1: Promote communication and partnerships between WCAHS and key stakeholders in the agricultural community. The agricultural community includes, but is not limited to, agricultural employees (farmworkers) and families; farmers and other agricultural employers and family members; commodity groups; government agencies; and community-based organizations, including *promotores* (lay community members trained as leaders and sources of information regarding occupational health) and advocacy organizations spanning the spectrum of the agricultural community. We maintain active communication with these groups, directly and through our Advisory Panel, to assure that the WCAHS focuses on the agricultural community's needs. Our tools for fostering partnership and communication range from in-person activities to traditional print and audio media to modern digital channels. Through these activities we have achieved close and trustworthy communication with our stakeholders, which has allowed us to identify and develop emerging projects.

Specific Aim #2: Promote dissemination and utilization of research findings and policy recommendations (Research to Practice, "R2P") in collaboration with WCAHS investigators. In addition to encouraging traditional academic outputs, such as professional publications and presentations at scientific meetings, we will organize forums and activities, including periodic meetings between Outreach Core Program staff and WCAHS investigators to strengthen and expand their outreach efforts. The WCAHS sponsors monthly seminars open to the scientific and policy communities and the public at large. We also support a wide range of internet-based communications such as web and Facebook pages, listservs, a science blog, YouTube videos, and Twitter feed. Engaging community members in the identification of priority topics, development of messages, and recording of videos in multiple languages is the most powerful way to ensure those messages will reach the target audience.

Specific Aim #3: Promote communication and collaboration between WCAHS investigators and colleagues at other agricultural health and safety centers. WCAHS' work in fostering communication and collaboration among the 10 national NIOSH-sponsored Agricultural Health and Safety Centers include our ongoing leadership in the Evaluator, Coordinator, and Outreach (ECO) group, leadership in regional and national symposia addressing agricultural health and safety, and contributions to the National Agricultural

Safety Database and a YouTube channel dedicated to agricultural health and safety. Videos produced by WCAHS are posted on the WCAHS YouTube channel and include educational videos, brief interviews of speakers from seminar series, and short descriptions of our various projects and their importance. In addition to social media, the Outreach Team works with other WCAHS staff as part of a communications committee to discuss the best ways to engage our audiences using social media and our website

WCAHS Outreach will continue to work with other NIOSH Centers to increase awareness of the research and educational efforts conducted by all centers as a whole.

B.2. What did you accomplish under these goals?

Increased funding to the WCAHS Outreach Core in the 2016–2021 cycle facilitated a dramatic expansion of WCAHS' outreach efforts. Between October 2016 and September 2021, the WCAHS Outreach Core conducted 350 outreach events which reached over 17,000 people and distributed over one million print resources to farmers and farmworkers.

Outreach Events

Outreach and education specialists delivered trainings on a variety of topics with a focus on heat illness prevention, sexual harassment prevention, pesticide safety, wildfire smoke exposure, and COVID-19 prevention. While most trainings are offered in English and Spanish, translators have been employed to assist in the training of Mixteco, Punjabi, and Hmong-speaking workers. Trainings targeted a wide range of stakeholders, including farmers/growers, farm labor contractors, agricultural supervisors, farmworkers, and community-based organizations. The training format and content was modified according to the audience's roles and responsibilities. Over 195 trainings were held during the funding cycle, reaching over 16,000 people. Trainings ranged in length from short 15-minute tailgate trainings held in the field to multiple-hour Train-the-Trainer (ToT) courses for agricultural employers and supervisors. The ToT format maximized the reach of important safety information through the subsequent dissemination by the supervisors to their workers, resulting in the education of more individuals than could be reached by a single WCAHS trainer. For example, at the Heat Illness Prevention ToTs in March and May 2018, each trained farmworker supervisor subsequently trained an average of 76 other workers. This was determined by WCAHS follow-up phone calls three months after the training event to determine what supervisors recalled from their training and how many workers they had trained. In total, 73 supervisors were reached for the follow-up, and they reported training approximately 5,550 farmworkers.

The Outreach Core engaged in an innovative partnership with the California Strawberry Commission to provide heat illness and sexual harassment prevention training for its members. In addition to enabling our team to reach over 1,600 supervisors, we also demonstrated the feasibility of a framework to provide trainings under a service agreement, in this case yielding an additional $16,500 in funds for outreach activities. The Outreach Core also collaborated with UC Integrated Pest Management to conduct pesticide applicator trainings in English and Spanish.

In 2020, the Outreach Core transitioned from conducting trainings primarily in-person, to almost exclusively online via Zoom due to the COVID-19 pandemic. The initial months of this transition required substantial work to modify the training material and format, including the identification of interactive activities for attendees. However, offering online trainings provided a unique opportunity to reach agricultural representatives who are unable to travel for training events due to the unpredictable nature of their work. We found that our Injury and Illness Prevention trainings experienced more than a 194% increase in participants per training from 2019/2020 to 2021 since switching to the online format. Supervisor-level heat illness trainings had a similar boost, and both Spanish and English-language courses had waiting lists. The Outreach Core will continue to host trainings online during the coming cycle, building upon the success of the last year, and will emphasize training promotion for audiences less likely to be able to attend in-person

events (e.g., those based in AZ, HI, NV, or in very rural settings far from where trainings are likely to be held).

From October 2020–September 2021, the Outreach Core provided 66 trainings and presentations about COVID-19 prevention, vaccines, and workers' rights to over 2,000 agricultural stakeholders via Zoom, Radio Bilingüe Latino public radio network, and Facebook Live with the Mexican Consulate in Fresno. The pandemic also highlighted a critical need for a trusted space for community leaders, volunteers, and farmworkers to discuss COVID-19 and workers' rights. In Spring 2021, *Pláticas en Confianza* (Conversations in Confidence) was piloted, and meetings were held via Zoom every second and fourth Monday of the month in the evenings to accommodate participant schedules. From May 2021 to September 2021, 10 *Pláticas* were hosted with a total of 438 participants overall.

Resources Developed and Distributed

From 2016–2021, WCAHS created training and safety resources for the agricultural community based on regulatory guidelines (e.g., regulations from the California Division of Occupational Safety and Health or Cal/OSHA), federally described best practices (e.g., COVID-19 public health guidance from the CDC), and WCAHS research findings. Center stakeholders, WCAHS investigators, and regulatory agencies were involved in the development process and reviewed all resources for accuracy and accessibility. By engaging center stakeholders during the development process, they were more invested in dissemination and adoption of the resources. A few topic-specific resources are described below, followed by an overview of the dissemination methods for the center.

Wildfire Smoke Exposure

WCAHS is a recognized leader in outreach relevant to the health and safety impacts of wildfire smoke exposure in the west. The center implemented NIOSH's priority of r2p through close collaboration with center investigators. Specifically, WCAHS led a NIOSH-funded study on the impacts of extreme weather events on western agriculture that assessed perceptions of risk and knowledge of protective measures (PI: Pinkerton). At the time, wildfire smoke exposure was less recognized by regulatory entities, such as Cal/OSHA, and neither growers nor farmworkers had extensive familiarity with safety responses. A community report was published that compared extreme weather-related safety concerns reported by farmers and farmworkers.

In 2019, WCAHS published the first wildfire training resources for agricultural employers including a worksite checklist and a training discussion guide and poster (Figure 1), based on the Cal/OSHA Protection from Wildfire Smoke regulation. To date, WCAHS has distributed over 10,000 training packets to agricultural employers. These materials are also posted on both the Cal/OSHA wildfire regulation webpage and the California Strawberry Commission website. In 2021, WCAHS developed a pocket card in English and Spanish describing when and how to use a respirator; over 64,000 have been distributed to farmworkers to date.

Heat Illness Prevention

In 2020, the Outreach Core collaborated with the heat illness research project team (PI: Schenker) to develop comprehensive training resources. Using an r2p approach, the training resources cover all elements required by California's heat standard and additional elements based on study findings. Resources included heat illness prevention discussion guides and visual aids for use by employers, safety officers, and supervisors in agricultural settings. Over 6,000 training packets were distributed to agricultural employers in the west. WCAHS also developed a bilingual safety resource on heat illness prevention for farmworkers and distributed it at outreach events and trainings, to community-based organizations who regularly interact with farmworkers, and to agricultural employers for distribution to their workers. Over 66,000 farmworker heat illness safety guides were distributed in 2021 alone. A short video about the importance of heat protections for workers was created in English and Spanish and shared during trainings and is featured on WCAHS' and the US Ag Centers YouTube channels.

COVID-19

The Outreach Core leveraged Emerging Issues funding to rapidly respond to the COVID-19 pandemic in early spring 2020. Guided by CDC recommendations and the WCAHS External Advisory Board, WCAHS published **a first-in-the-nation COVID-19 worksite checklist and employer training guide specifically for the agricultural industry** on April 14, 2020. The materials were reviewed by Cal/OSHA and served as a starting point for the state's subsequent guidance materials. The WCAHS resources were updated when Cal/OSHA adopted an emergency temporary regulation for COVID-19 on November 30, 2020, and a laminated poster was designed to accompany the training discussion guide. Over 14,000 COVID-19 training kits were mailed to growers and agricultural employers, with another 2,793 training kits downloaded from the website. Additional print resources were developed for dissemination to farmworkers by community-based organizations and agricultural employers, including COVID-19 prevention information pocket cards, infographics, a COVID-19 vaccine information postcard, and an illustrated COVID-19 prevention flip chart for community-based organizations to use in presentations to farmworker communities. Due to their increased risk of exposure in shared housing and transportation situations, specific resources were created for agricultural workers temporarily in the country on the H-2A visa program. These resources included a workers' rights postcard and a COVID-19 prevention information pocket card. With funding from the California Labor and Workforce Development Agency, over 440,000 of these print resources were sent to community-based organizations and employers for dissemination to farmworkers.

Over 77 COVID-19 public health messages were created for farmworkers in over 20 languages in partnership with community-based organizations. These videos were critical for Indigenous language-speaking farmworkers who have low Spanish literacy and whose native language is largely unwritten. In total, the WCAHS COVID-19 videos were viewed over 14,000 times on the center's YouTube channel alone, not including views from social media posts and shares from other organizations. Outreach specialists also created graphics designed for community-based organizations to share via social media or WhatsApp with their farmworker communities. These graphics provided important COVID-19 updates and workers' benefits information (e.g., COVID-19 supplemental paid sick leave).

All COVID-19 resources were housed on the center website, which included articles and information pages about testing, vaccines, employer responsibilities, and training requirements. These webpages provided practical guidance for how to prevent and respond to COVID-19 in the agricultural workplace and had 51,104 total pageviews March 2020—September 2021. They were also linked to by over 90 industry, community, and governmental agricultural organizations nationwide.

Other Topics

As part of the NIH-funded *Pasos Saludables* (Healthy Steps) project, a diabetes prevention *fotonovela* (comic book) was created in English and Spanish in partnership with community educators at California AgrAbility and Dignity Health and distributed to community-based organizations at events and via direct mail. The *fotonovela* follows the story of a farmworker who is diagnosed with diabetes and the behavioral changes that he makes with the help of his family to manage it. A bilingual sexual harassment prevention pocket card was created to help farmworkers easily identify key safety messages about what constitutes sexual harassment, workers' rights, and how to respond in the workplace. This is one of our most frequently requested resources and was distributed by WCAHS outreach staff at events and trainings to community-based organizations, employers, supervisors, and other organizations.

B.3. Competitive Revisions/Administrative Supplements

Year 6 – additional year of funding through NIOSH. See B2 for accomplishments associated with Year 6 activities.

B.4. What opportunities for training and professional development did the project provide?

WCAHS magnifies the impact of the Outreach Core through strategic partnerships and subawards with other universities and organizations in the western region. In 2017, the center funded the Health Initiative of the Americas (HIA) at the UC Berkeley School of Public Health to develop and launch an online certificate program for *promotores*. HIA also conducted a large annual training conference for approximately 300 *promotores* in May 2017. Building on this model, WCAHS launched an outreach funding opportunity to expand and enhance the topical and regional reach of WCAHS and facilitate stronger collaboration between cooperative extension personnel, academic and private educators, and community organizations. Requests for proposals were released in June 2018, 2019, and 2020 for awards of up to $10,000. WCAHS funded 11 projects for a total of $96,000. Below are highlights from just a few of the funded projects.

1) PI: AgSafe, 2019–2020, 2020–2021
Title: Hawaii Agricultural Safety and Pesticide Safety Webinar Series
Hawaiian growers often face innumerable challenges because they are thousands of miles away from traditional supply chains and resources. There is a desire and need for diverse learning opportunities and resources. This project aimed to reduce barriers to learning opportunities for growers with the development of online safety training webinars. In the first year of funding, AgSafe partnered with the pesticides branch of the Hawaii Department of Agriculture to develop a four-part pesticide safety webinar series, which discussed worker protection standards in Hawaii, and employer and handler responsibilities and requirements. The training was well attended, and participants were highly engaged, indicating the need for future training opportunities. In the second year of funding, AgSafe partnered with University of Hawaii Cooperative Extension Service and the Hawaii Department of Agriculture to deliver an agricultural safety webinar series in May 2021, which discussed equipment safety, sexual harassment prevention, and the worker protection standard for heat illness.

2) PI: O'ahu Resource Conservation & Development Council, 2018–2019
Title: Health and Safety Outreach for Hawaii's Women Farmers
Recent shifts away from plantation-style agriculture in Hawaii toward diversified agriculture have created opportunities for small and medium-sized farms with women in leadership and management roles. O'ahu Resource Conservation & Development Council (O'ahu RC&D) used funds from the outreach grant to create safety resources for their network of women farmers and ranchers throughout Hawaii. In October 2018, three on-farm workshops were held to connect women farmers and ranchers and build their agribusiness skills, a Facebook group was established to facilitate connections (which currently has over 700 members), information on women's health and sexual harassment was distributed through social media and newsletters, and O'ahu RC&D hosted a forum at the 2019 Hawaii Ag Conference.

3) PI: Radio Bilingüe, 2018–2019
Title: Development of Farmworker Health & Safety Educational Materials in Mixteco and Spanish
Radio Bilingüe, the leading U.S. public radio producer and broadcaster serving Latino and Indigenous farmworkers, has a decades-long history of developing and implementing culturally appropriate outreach on worker safety and rights via the highly popular medium of radio among low-literacy farmworkers in their languages. They collaborated with the California Labor and Workforce Development Agency to develop six 60-second educational messages in Mixteco and Spanish to educate Indigenous farmworkers about labor rights (e.g., wages, safety training, sick leave) and tractor safety. The audio messages aired on Radio Bilingüe's stations throughout California's agricultural regions.

4) PI: Campesinos Sin Fronteras, 2018–2019
Title: Pesticide Safety Training for Farmworkers in Arizona
Campesinos Sin Fronteras is a non-profit organization based in Somerton, Arizona, dedicated to educating members of the low-income, migrant, agricultural community. They partnered with local *promotoras* to adapt and present the Jose Aprende Children Pesticide Safety Education Promotora Program (JACPSEPP) to farmworker families at local migrant Head Starts in agricultural communities in Arizona. *Promotoras* incorporated children's puppets to the JACPSEPP curriculum to make the classes more appealing to children. In addition to family trainings, Campesinos collaborated with the Arizona Department of Agriculture

to provide ToT farmworker safety presentations in Somerton, Arizona and pesticide safety trainings to 100 farmworkers from the Harrison and Lee Farms in Yuma, Arizona.

5) PI: Ag Health and Safety Alliance, 2019–2020
Title: Evaluating Effectiveness of Story-Telling Tools in the Gear Up for Ag Health and Safety™ Classroom: Personal Protective Equipment (PPE) and Appropriate Use of PPE During Emergency Response
The Gear Up for Ag Health and Safety™ program includes current evidence-based content, interactive demonstrations, and distribution of PPE to high school and college-age students involved in agriculture in the U.S., Canada, Australia, and Scandinavia. This project developed new resources and an in-classroom story card activity discussing the importance of appropriate use of PPE in emergency scenarios such as wildfires, flooding, and zoonotic disease. The story card activity will be tested at the University of Arizona and Arizona West-MEC high schools (pre-vet programs) at a future date.

B.5. How did you disseminate the results to communities of interest?

To benefit research and outreach information dissemination, in the 2016–2017 academic year, the WCAHS website and logo underwent a major update and with it, a move to a campus-supported, streamlined Drupal-based content management system. The website is available in English and Spanish, the primary languages of many of the center's stakeholders. There were over 300,000 total pageviews on the new website from 2017–present, with wildfires, heat illness, and COVID-19 as the main topics of interest for both research and training-specific pages.

WCAHS' monthly email newsletter featured research and outreach activities, funding opportunities, and events and was marketed to a broad audience, including students, faculty, industry, and organizations. The newsletter was delivered to approximately 1,200 subscribers in 2021, an increase of 57% in the last four years. The bilingual outreach and training email newsletter, *Próximamente* (Coming Soon), featured safety tips, timely regulatory reminders, and upcoming trainings and community events for the agricultural community, including farmers, supervisors, and training attendees. This more targeted newsletter was very effective, and in just over three years, the subscriber list increased by more than 9-fold (from 99 to 978 subscribers) and the average open rate was 40%.

WCAHS also refined its use of social media (Twitter, Instagram, Facebook, and YouTube) to strategically connect with agricultural stakeholders throughout the region. The center currently uses Twitter to connect with other researchers, universities, and industry organizations; Instagram for community-based and farmworker organizations and small farmers; and Facebook for community-based organizations. Dissemination of WCAHS expertise and resources via YouTube was particularly valuable for making monthly seminar series videos and multilingual COVID-19 messages publicly available. With increasingly targeted messaging, the center has seen an overall increase in engagement and followers, and a 36-fold increase in views from 2017 to 2021.

B.6 - What do you plan to do during the next reporting period to accomplish the goals?
N.A.

C. PRODUCTS

C.1. Publications, conference papers, and presentations
See overall section

C.2. Website(s) or other Internet site(s) – include URL(s)

Center website: https://aghealth.ucdavis.edu/
Facebook: https://www.facebook.com/AgHealthUCD
Twitter: https://twitter.com/AgHealthUCD
Instagram: https://www.instagram.com/aghealthucd/
YouTube: https://www.youtube.com/channel/UCCrF9GcijzIdd2shYwCFGjw

C.3. Technologies or techniques
N.A.

C.4. Inventions, patent applications, and/or licenses
N.A.

C.5. Other products and resource sharing

Print Resources
Ag Health and Safety Alliance and Western Center for Agricultural Health and Safety. April 19, 2021. Story Card Activity for Identifying Hazards and PPE. English: https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/inline-files/Facilitator%27s%20Guide%20and%20Story%20Cards_AHSA_English.pdf; Spanish: https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/inline-files/Facilitator%27s%20Guide%20and%20Story%20Cards_AHSA_Spanish.pdf

Ag Health and Safety Alliance, Great Plains Center for Agricultural Health, and Western Center for Agricultural Health and Safety. June 5, 2020. Cloth Face Covering Infographic. https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/files/page/Cloth%20Face%20Covering%20Graphic_FINAL.pdf

Andrews T, Mandujano E, Riden H, Schenker M, Schilli K, Varela H, Zapalac, M. September 23, 2021. Diabetes Fotonovela, “The 5 Healthy Steps for the Prevention of Diabetes”. English: https://indd.adobe.com/view/b15d1c66-6649-4b34-8604-f21dc20e1608; Spanish: https://indd.adobe.com/view/ed6f3c35-542f-4661-a9e3-682397132b3f

California Agricultural Labor Relations Board and Western Center for Agricultural Health and Safety. July 27, 2021. COVID-19 Workers’ Rights Handout. https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/ALRB_Spanish_Indio_no%20bleeds.pdf

LA Grit Media, UC Berkeley Labor Occupational Health Program, UCLA Labor Occupational Safety and Health Program, and Western Center for Agricultural Health and Safety. April 23, 2020. Protecting Agricultural Workers from COVID-19 Infographic. English: https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/files/page/ENGLISH-UCLA-LOSH-Farmworkers-COVID-Infographic.pdf; Spanish: https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/files/page/SPANISH-UCLA-LOSH-Farmworkers-COVID-Infographic.pdf

LA Grit Media, UCLA Labor Occupational Safety and Health Program, and Western Center for Agricultural Health and Safety. August 25, 2020. Protecting Agricultural Workers from COVID-19 Infographic Wallet Card.

https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/files/page/Wallet%20Card%20COVID%20Infographic_EDITABLE_FINAL.pdf

LA Grit Media, UCLA Labor Occupational Safety and Health Program, and Western Center for Agricultural Health and Safety. September 22, 2020. COVID-19: Symptoms, safety precautions, and farmworker resources Infographic. English: https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/infographic_testpositive_english_nobleeds.pdf; Spanish: https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/Infographic_testpositive_Spanish_nobleeds.pdf

Wells L. and Western Center for Agricultural Health and Safety. March 19, 2021. COVID-19 Employer Responsibilities Pocket Card. https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/COVID_spanish_editable_PC_halfsheet_11.pdf

Wells L. and Western Center for Agricultural Health and Safety. March 19, 2021. COVID-19 Vaccine Information Postcard. English: https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/COVID-19%20Vaccine%20Postcard_English_11.15.2021.pdf; Spanish: https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/COVID-19%20Vaccine%20Postcard_Spanish_11.15.2021.pdf

Wells L. and Western Center for Agricultural Health and Safety. April 20, 2021. COVID-19 H-2A Workers' Rights Pocket Card. https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/H-2A%20Pocket%20Card_11.15.2021.pdf

Wells L. and Western Center for Agricultural Health and Safety. June 28, 2021. H-2A Workers' Rights Postcard. https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/H2A_postcard_11.15.2021.pdf

Western Center for Agricultural Health and Safety. February 6, 2017. 2017 Heat-related Illness Informational Flyer. https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/HRI%20Flyer_2017.pdf

Western Center for Agricultural Health and Safety. February 21, 2017. WCAHS Informational Brochure. https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/WCAHS%20Brochure_FINAL.pdf

Western Center for Agricultural Health and Safety. January 17, 2018. 2018 Heat-related Illness Informational Flyer. https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/HRI%20Flyer_2018.pdf

Western Center for Agricultural Health and Safety. March 9, 2018. WCAHS Donation Postcard. https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/Ag%20Center%20Donation%20Card%20.pdf

Western Center for Agricultural Health and Safety. March 16, 2018. WCAHS Informational Pocket Card. https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/Pocket%20Card_BIL.pdf

Western Center for Agricultural Health and Safety. May 24, 2018. Heat Illness Prevention Emergency Pocket Card. https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/HRI%20Emergency%20Card.pdf
Western Center for Agricultural Health and Safety. June 22, 2018. Sexual Harassment Prevention Fact Sheet. https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/SHP%20Fact%20Sheet.pdf

Western Center for Agricultural Health and Safety. August 24, 2018. Outreach Promotional Postcard. https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/Postcards_4x6_FINAL.pdf

Western Center for Agricultural Health and Safety. November 1, 2018. Sexual Harassment Prevention Accordion. https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/files/page/SHP%20Accordion_v2.pdf

Western Center for Agricultural Health and Safety. November 2, 2018. Heat Illness Prevention Accordion. https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/HRI%20Accordion_v2_0.pdf

Western Center for Agricultural Health and Safety. October 8, 2019. Wildfire Smoke Worksite Checklist. https://aghealth.ucdavis.edu/wildfires

Western Center for Agricultural Health and Safety. October 8, 2019. Wildfire Smoke Employer Training Discussion Guide and Poster. https://aghealth.ucdavis.edu/wildfires

Western Center for Agricultural Health and Safety. March 30, 2020. COVID-19 Worksite Checklist. English: https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/COVID-19%20Employer%20Checklist_English_6.2.2020.pdf; Spanish: https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/COVID-19%20Employer%20Checklist_Spanish_6.2.2020.pdf

Western Center for Agricultural Health and Safety. April 14, 2020. COVID-19 Employer Training Discussion Guide and Poster. English: https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/COVID-19%20Discussion%20Guide%20%26%20Training%20Poster_ENGLISH_10.28.2021.pdf; Spanish: https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/COVID-19%20Discussion%20Guide%20%26%20Training%20Poster_SPANISH_10.28.2021.pdf

Western Center for Agricultural Health and Safety. December 14, 2020. COVID-19 Safety Pocket Card for Community-based Organizations. https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/CCEJN%20Pocket%20Card_8.3.2021.pdf

Western Center for Agricultural Health and Safety. February 9, 2021. Heat Illness Prevention Training Guides. https://aghealth.ucdavis.edu/training/heat-illness

Western Center for Agricultural Health and Safety. March 3, 2021. COVID-19 Overview PowerPoint. English: https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/COVID19Basics_English_web_10.18.2021_0.pptx; Spanish:

https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/COVID19Basics_Spanish_web_11.2.2021.pptx

Western Center for Agricultural Health and Safety. March 12, 2021. COVID-19 Flip Chart for Community-based Organizations. English: https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/Flip%20Chart_English_3.12.2021-compressed.pdf; Spanish: https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/Flip%20Chart_Spanish_3.16.2021-compressed.pdf

Western Center for Agricultural Health and Safety. April 27, 2021. Workers' Rights Flip Chart for Community-based Organizations. English: https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/Workers%27%20Rights%20Flip%20Chart_English_11x17-compressed_0.pdf; Spanish: https://aghealth.ucdavis.edu/sites/g/files/dgvnsk261/files/media/documents/Workers%27%20Rights%20Flip%20Chart_Spanish_11x17-compressed_0.pdf

Western Center for Agricultural Health and Safety. August 26, 2021. Respirator Pocket Card. https://aghealth.ucdavis.edu/wildfires

D. PARTICIPANTS

D.1. What individuals have worked on the project? Please include calendar, academic, and summer months.

Commons ID	S/K	Name	Degrees(s)	Role	Cal	Aca	Sum	Foreign	Country	SS
		Andrews, Teresa		PRG REPR 3, Community Education Specialist 3	17.95					
		Arana, Victoria		Student 4	1.13					
		Flores, Isabel		CMTY HEALTH PRG REPR, Community Education Specialist 2	11.2					
		Lee, Deandra S		Survey Researcher 2	0.36					
		Olivares, Leslie V		Jr. Specialist, CMTY HEALTH PRG REPR, Community	23.09					

				Education Specialist 3						
		Ramirez Sigala, Yajaira		Community Education Specialist 3, Jr. Specialist, Student 3	4.29					
		Riden, Heather E		4330, 9349, Academic Program Management Officer 3 & 4	3.93					
		Rodriguez, Lillibeth A.		Student 3	0.71					
		Schilli, Kara M.		Community Specialist 3	22.18					
		Silva-Mora, Rigoberto		Blank Assistant 2, Community Education Specialist 2	2.07					
		Simmons, Christopher W.		Associate Researcher, Researcher	2.74					
		Smiley-Jewell, Suzette M.		EDITOR PRN	1.48					
		Zuniga Hernandez, Jasmine		Student 4	1.83					

D.2 Personnel updates

N.A.

E. IMPACT

E.1 - What is the impact on the development of human resources, if applicable?

N.A.

E.2 - What is the impact the Public Health Relevance and Impact? The investigator should address how the findings of the project relate beyond the immediate study to improved practices, prevention or intervention techniques, legislation, policy, or use of technology in public health.

The overall goal of the WCAHS Outreach Core was and continues to be advancing agricultural health and safety by facilitating knowledge acquisition and behavior change about occupational risks for illness and injuries in the agricultural industry via translation of research findings and regulatory standards into practical

solutions. The Outreach Core achieved this goal during the 2016–2021 cycle by conducting 350 outreach events which reached over 17,000 people and distributed over one million print resources to farmers and farmworkers.

In addition, WCAHS formed strong relationships with California state agencies to promote health and safety in agriculture. During the 2016–2021 funding cycle, WCAHS leveraged the center's expertise to secure three contracts to extend outreach and training efforts for specific populations and topics. State funding exceeded $5.6 million. In addition, the Employment Development Department of California sought input from the WCAHS on training content and format to enhance the utility and cultural competency of its sexual harassment prevention in agriculture curriculum. Funding from these contracts enabled the Outreach Core to bolster its resource development, training delivery, and material distribution. Additionally, WCAHS formed relationships with the following agencies:

- The California Department of Industrial Relations funded WCAHS through the Worker Occupational Safety and Health Training and Education Program to reduce injury and illness in California's workers through trainings and special projects focused on the agricultural industry (PI: Riden, 10/19–10/22, $337,500).
- In 2018, WCAHS partnered with the California Department of Pesticide Regulation to conduct a needs assessment for pesticide safety resources for Indigenous language-speaking farmworkers (PI: Riden, 6/18–3/20, $275,000).
- Most recently, the California Labor and Workforce Development Agency funded WCAHS to lead a statewide COVID-19 outreach and training program (PI: Riden, 10/20–6/22, $4,927,264).
- The USDA NIFA funded California AgrAbility and WCAHS as part of the Western Regional Agricultural Stress Assistance Program to host conferences for *promotores*, and to create a community partnership guide to assist researchers in developing productive relationships with local communities (PI: Fathallah, 9/20–8/22, $77,948).

F. CHANGES

F.1 – Changes in approach and reasons for change, including changes that have a significant impact on expenditures
N.A.

F.2 - Actual or anticipated challenges or delays and actions or plans to resolve them
N.A.

F.3 - Significant changes to human subjects, vertebrate animals, biohazards, and/or select agents
N.A.

G. Special Reporting Requirements

G.1 Special Notice of Award Terms and Funding Opportunities Announcement Reporting Requirements
N.A.

G.2 Responsible Conduct of Research

G.3 Mentor's Research Report or Sponsor Comments

N.A.

G.4 Human Subjects
G.4.a Does the project involve human subjects?
N.A.

G.4.b Inclusion Enrollment Data
N.A.

G.4.c ClinicalTrials.gov
N.A.

Does this project include one or more applicable clinical trials that must be registered in ClinicalTrials.gov under FDAAA?
N.A.

G.5 Human Subject Education Requirement
Are there personnel on this project who are newly involved in the design or conduct of human subject's research?
N.A.

G.6 Human Embryonic Stem Cells (HESCS)
Does this project involve human embryonic stem cells (only hESC lines listed as approved in the NIH Registry may be used in NIH funded research)?
No

G.7 Vertebrate Animals
Does this project involve vertebrate animals?
No

G.8 Project/Performance Sites
UC Davis

G.9 Foreign Component
No

G.10 Estimated Unobligated Balance
G.10.a Is it anticipated that an estimated unobligated balance (including prior year carryover) will be greater than 25% of the current year's total approved budget?
N.A.

G.11 Program Income
Is program income anticipated during the next budget period?
No

G.12 F&A Costs
Is there a change in performance sites that will affect F&A costs?
No

I. OUTCOMES

I. Provide a concise summary of the outcomes or findings of the award, written for the general public in clear and comprehensible language, without including any proprietary, confidential information or trade secrets

Note: project outcome information will be made public in NIH RePORTER

Increased funding to the WCAHS Outreach Core in the 2016–2021 cycle facilitated a dramatic expansion of WCAHS' outreach efforts. Between October 2016 and September 2021, the WCAHS Outreach Core conducted 350 outreach events which reached over 17,000 people and distributed over one million print resources to farmers and farmworkers. The overall goal of the WCAHS Outreach Core was and continues to be advancing agricultural health and safety by facilitating knowledge acquisition and behavior change about occupational risks for illness and injuries in the agricultural industry via translation of research findings and regulatory standards into practical solutions. To realize this goal, the WCAHS Outreach Core: 1) developed and disseminated safety information, resources, and training materials; 2) conducted trainings and events; 3) funded outreach grants; and 4) formed strong relationships with California state agencies, garnering over $5.6 million in additional funds.

Western Center for Agricultural Health and Safety

Christopher W. Simmons, Ph.D.

Pilot and Feasibility Program: Funding, Professional Development, and Outreach

B. ACCOMPLISHMENTS

B.1. What are the major goals of the project?

Western agriculture is continually evolving in technology, environment, and labor force, resulting in an ever-changing health and safety landscape. New investigators and approaches are required to adapt to these changes. The Western Center for Agricultural Health and Safety (WCAHS) will employ a Pilot/Feasibility Program to promote research in agricultural health and safety through the provision of research funding, access to center resources, and intellectual support. The Pilot/Feasibility Program will encourage the generation of new resources by enabling investigators to explore new research directions, collect preliminary data, or test new methods and technologies. The program will enhance the mission of the center by bringing together faculty, postdoctoral fellows, and students across numerous disciplines through a shared focus on agricultural health and safety research.

The overarching goal of the WCAHS Pilot/Feasibility Program is to encourage the development of creative research projects while nurturing researchers—particularly early-career researchers—interested in improving agricultural health and safety. To this end, the program has the following specific aims:

Aim 1: Support short-term research projects with a high likelihood of leading to further funding from extramural sources. An important goal of the Pilot/Feasibility Program is to foster the next generation of agricultural health and safety researchers by facilitating the collection of preliminary data and/or development of new methodologies needed to be competitive for an extramurally funded R01 or equivalent.

Aim 2: Provide a means for involving investigators new to the center or who are not currently part of the center to study agricultural health and safety. A main goal of the program is to draw non-center investigators into the study of agricultural health and safety and membership in the center.

Aim 3: Facilitate the exploration of new and innovative directions with the potential to advance agricultural health and safety. For extramurally funded grants, the peer review process by its nature tends to be conservative, passing up exciting but risky ventures for tried-and-true projects that are more likely to yield solid and important data, but will lead to a true breakthrough only occasionally. We expect that this Pilot/Feasibility Program will permit the investigation of risky but highly innovative and cutting-edge approaches.

Aim 4: Provide funding opportunities for graduate student research. The Pilot/Feasibility Program will facilitate graduate students across multiple disciplines to incorporate agricultural health and safety research in their training.

B.2. What did you accomplish under these goals?

From 2016–2021, WCAHS at the University of California, Davis invested over $700,000 of center funds in research projects. The Pilot/Feasibility Program funded research that addressed agricultural health and safety in Arizona, California, Hawaii, and Nevada. Applications on a wide range of topics were encouraged. Pilot/Feasibility grants were awarded to graduate students and postdoctoral scholars up to $10,000 and faculty were able request up to $30,000.

From 2016–2021, WCAHS funded a total of 54 Pilot/Feasibility grants, with four conducted in Arizona, 48 in California, one in Hawaii, and one in Nevada. The investigators funded highlight our track record of successfully reaching graduate students and cooperative extension specialists, as well as attracting established investigators, to explore topics related to agricultural health and safety. Many of the grants funded had aims and outcomes that could be applied broadly to agriculture in the western U.S. and beyond, such as youth operating ATVs, Valley Fever (coccidioidomycosis), mental health, and wildfire smoke exposure. Pilot/Feasibility Program outputs include 15 publications and 110 presentations. Funded investigators submitted 36 external grant proposals based on their WCAHS-funded findings, and 11 were funded. Below, we first list all projects funded by the Pilot/Feasibility Program (Table 1), and then we highlight selected projects funded from 2016 to 2021.

Table 1. All 54 Pilot/Feasibility grants funded during this renewal cycle.

Funding Year	Name	Project Title	State
2020-2021	Tim Beatty	Continuous Surveillance of Agricultural Workers Occupational Health and Injuries	CA
2020-2021	Stephanie Guardado	The Impact of LCN2 in Lung Inflammatory Response to Agricultural Dust Exposure	CA
2020-2021	Farzaneh Khorsandi	Evaluating the Stability of Agricultural All-Terrain Vehicles	CA
2020-2021	Sanjai Parikh	Examining the Impact of Nanopesticides and Nanofertilizers on Farmworker Safety	CA
2020-2021	Daniel Sumner	The Effects of Air Quality on Economics of Farm Worker Productivity	CA
2020-2021	Adrianne Keeney	Understanding COVID-19 Testing and Vaccine Access for Daytime Farmworkers in Imperial County	CA
2020-2021	Gerald Ackerman	Student Outreach Clinic – Fall Harvest	NV
2020-2021	Nathan Harkelroad	Pandemic and Wildfire Smoke Safety (PAWSS) Project	CA
2020-2021	Keith Bein	Chemico-Toxicological Assessment of Potential Impacts of Wildfire Emissions on Farmworker Health	CA
2020-2021	Shiori Echizenya	Potential Risks to Wearers of Face Masks: Inhalable Particulates from Facial Mask Debris from New and Used Face Masks: Pathogen Detection from Reused Face Masks	CA
2020-2021	Jesus Fernandez Bayo	Promotion of naturally occurring biopesticides from date industry by-products to reduce workers exposure to chemical fumigants	CA
2020-2021	Robert Gunier	Agricultural use of 1,3-Dichloropropene and emergency department visits for asthma in California from 2013 to 2017	CA
2020-2021	Savannah Hunter	Valley Fever	CA
2020-2021	Miriam Marlier	Agricultural Worker Exposure to Wildfire Smoke Pollution in California During the 2020 Fire Season	CA
2020-2021	Marc Schenker	Cannabis industry occupational health and safety stakeholder meeting	CA

2020-2021	Xiang (Crystal) Yang and Xunde Li	A rapid study on occupational exposure to antibiotic resistant bacteria in poultry farming	CA
2019-2020	Kathryn Conlon	Evaluating the Implementation of an Emergency Regulation to Protect California's Outdoor Workers from Wildfire Smoke Exposure	CA
2019-2020	Marc Schenker	Cannabis worker health and safety	CA
2019-2020	Farzaneh Khorsandi and Alireza Pourreza	Ability of Youth Operators to Reach Agricultural All-Terrain Vehicle Controls	CA
2019-2020	Katie Lee	Occupational Exposure to Antimicrobial Resistant Bacteria and Genes in Dairy Farm Environments	CA
2019-2020	Alvaro Medel-Herrero	Policies of Exclusion: Understanding the Impact of the Current Immigration Policy on Self-reported Health, Healthcare Access, and Participation in Public Programs Among California Hired Mexican Agricultural Workers and Their Families	CA
2019-2020	Laura Stock	Exploring Agriculture Workers' Exposure to and Experience with Wildfires	CA
2019-2020	Xiang (Crystal) Yang and Xunde Li	Assessment of Worker Exposure to Antimicrobial Resistant Genes from Dairy and Beef Cattle Operations	CA
2018-2019	Jayveeritz Bautista	Metal and Inorganic Particulates in the Lungs of California Agricultural Workers	CA
2018-2019	Reina Engle-Stone	Food Security and Nutritional Status among Agricultural Workers in the CA Central Valley: Pilot Study	CA
2018-2019	Jesus Fernandez Bayo	Preliminary assessment of risk of exposure to aflatoxin of workers in the almond industry	CA
2018-2019	Skye Kelty	Knights Landing Environmental Health Project	CA
2018-2019	Matthew Bridges	Organizing for a better life: The Yolo County farmworker advocacy project	CA
2018-2019	Seth Holmes	A Qualitative Study of the Mental Health and Alcohol Use of Indigenous Mexican Farmworker Youth	CA
2018-2019	Farzaneh Khorsandi	Developing a Test Station to Evaluate Performance of Crush Protection Devices in Agricultural ATV Rollover Accidents	CA
2018-2019	Alvaro Medel-Herrero	Exploring Stressors and Psychological Distress of Hired Mexican Migrant Agricultural Workers in California	CA
2018-2019	Rietta Wagoner and Nicolas Lopez-Galvez	Heat Exposure and Kidney Functioning in Migrant Farmworkers in the Arizona–Sonora Border Region	AZ
2018-2019	Farzaneh Khorsandi	Forces Required to Operate Controls on Agricultural All-Terrain Vehicles: Implications for Young Operators	CA
2017-2018	Chris Vogel	Differential characterization of air pollutant emissions and associated toxicity from	CA

		common agricultural practices in the San Joaquin Valley	
2017-2018	Jesus Fernandez Bayo	Reducing exposure of farmworkers to soil chemical fumigants by promoting sustainable, chemical-free alternatives	CA
2017-2018	Farzaneh Khorsandi	All-Terrain Vehicle Rollover Hazards and Interventions	CA
2017-2018	Michelle Ko	Healthcare in the San Joaquin Valley: Describing the Physician Population in a Diverse Agricultural Region	CA
2017-2018	Savannah Mack	Respiratory health effects of airborne particulate matter from the Salton Sea: A community-based exploratory project	CA
2017-2018	Megan Ouyang	Poultry Health and Biosecurity Management through Youth Education in California and Nicaragua	CA
2017-2018	Farzaneh Khorsandi	Developing and implementing an outreach program to improve cannabis worker safety and health in California	CA
2017-2018	Marc Verhougstraete	A Water Quality Assessment in a Farmworker Community	AZ
2017-2018	Alvaro Medel-Herrero	Leptospirosis Among California Agricultural Workers—A Silent Epidemic?	CA
2017-2018	Nathan Harkelroad	Farm Incubator Agricultural Safety Training	CA
2017-2018	Katie Edwards	The Correlation of Metal-Specific Dusts to Lung Pathology in California Agricultural Workers	CA
2017-2018	Monica Cooper	Organizational Risk Factors for Sexual Harassment and the Consequences for Agricultural Work Teams	CA
2017-2018	Sanjai Parikh	Chemical Compositions of Thomas Fire Ash and its Potential Health Risks to Farmworkers During Agriculture Recovery	CA
2017-2018	Marc Schenker	Cannabis worker health and safety	CA
2016-2017	Erin Hamilton	Legal Status and the Health of U.S. Farmworkers	CA
2016-2017	Paloma Beamer	Arizona's Pesticide Use Registry and Vital Statistics Birth Certificates	AZ
2016-2017	Seth Holmes	A Contextual Study of the Health and Safety of Indigenous Mexican Farmworker Youth	CA
2016-2017	Skye Kelty	Knights Landing Environmental Health Project	CA
2016-2017	Lynette Landry	Characterizing the Agricultural Workforce in Hawaii	HI
2016-2017	Stephen McCurdy	Sexual Harassment in Agriculture	CA
2016-2017	Gerry Lopez	Arizona Dairy Farm Worker Zoonotic Exposure Assessment	AZ

1) Erin Hamilton, Ph.D., UC Davis, 2016–2017
Title: Legal Status and the Health of U.S. Farmworkers

The health hazards of farm work are well known, but it is not clear how farmworker health varies by immigrant legal status. More than half of U.S. farmworkers are unauthorized immigrants. While research suggests unauthorized immigrants are extremely vulnerable which may lead to poorer health, this study found the opposite. Investigators reviewed data from the U.S. Department of Labor's National Agricultural Workers Survey (NAWS) from 2000–2016, which included data from naturalized citizens, Green Card holders, temporary visa holders, and people unauthorized to work. Unauthorized farmworkers' health (including chronic conditions and musculoskeletal pain) was better than that of legal permanent residents (Green Card holders) and naturalized citizens. It is possible that the challenges of migrating to the U.S. and working as an unauthorized migrant may require good health. This means that unauthorized workers are drawn from a healthier population than the pool of authorized migrants. However, more research is needed to confirm the pattern observed in this study and to understand its implications. This project positioned Dr. Hamilton to publish three papers, receive a William T. Grant Scholars grant, and give numerous presentations.

2) Monica Cooper, Ph.D., UC Agriculture and Natural Resources, 2017–2018
Title: Organizational Risk Factors for Sexual Harassment and the Consequences for Agricultural Work Teams
This project examined the relationship between incidence of sexual harassment, work team factors that facilitate sexual harassment, and the consequences for vineyard workers. Investigators surveyed 295 workers in Napa County, California. Of the female workers, 30% reported experiencing offensive comments, jokes, and gestures in their current employment. A further 9% of these women reported unwanted sexual attention and 2% reported sexual coercion. Consequently, harassed women were more likely to intend to leave their current jobs than non-harassed women. The harassment also had a negative effect on male co-workers, who were more dissatisfied with their jobs when working in a crew where sexual harassment occurred. Surveys indicated that younger women and seasonal workers may be particularly vulnerable to sexual harassment. Findings suggest that improvements to the structure and administration of sexual harassment trainings to agricultural workers should be explored and that sexual harassment should be addressed across the organization or the industry as a whole, rather than at the level of the work team that was the focus of this study.

3) Sanjai Parikh, Ph.D., UC Davis, 2017-2018
Title: Chemical Compositions of Thomas Fire Ash and its Potential Health Risks to Farmworkers During Agriculture Recovery
Ventura County California agriculture suffered $171 million in damages to over 70,000 acres of land during the Thomas Fire in 2017. In the fire's aftermath, farmworkers worked to clear debris and repair irrigation pipes, which may have exposed them to arsenic, cadmium, and other toxic elements. Investigators collected ash samples in the affected areas to evaluate health risks. The ash samples contained significantly higher concentrations of toxic elements than did the corresponding soil samples from both the burnt and unburnt areas. There were similar levels of hazardous chemicals in both the ash and soil samples. In addition, ash samples are more prone to be emitted as dusts during agricultural activities compared to soils beneath. In the hazard quotient analysis, which calculated the health risks caused by inhalation of toxic elements and hazardous chemicals, it was found that working on ash-covered sites could pose a higher health risk to farmworkers compared to those working on non-impacted soil. The researchers concluded that the increasing frequency and severity of wildfires could lead to heightened health risks for farmworkers working with soil and ash in burnt areas. They recommend that policy makers pay extra attention to the health risks of farmworkers working in areas recovering from a wildfire and/or in areas with repeated wildfires. Study findings were published in the *Journal of Environmental Management* and referenced by California lawmakers in a bill to ensure workers have access to necessary respiratory protection.

4) Seth Holmes, Ph.D., UC Berkeley, 2018–2019
Title: A Qualitative Study of the Mental Health and Alcohol Use of Indigenous Mexican Farmworker Youth

To explore the risk and protective factors affecting alcohol misuse, anxiety disorders, and depression among Indigenous Mexican farmworker youth, this project conducted in-depth ethnographic research including

collaborative participant observation, interviews, and videography among Indigenous Mexican farmworkers as they migrate between California, Washington State, and southern Mexico. While research indicates increased rates of alcohol misuse and mental health problems among Latino/a farmworkers, little research has focused on Indigenous Mexican farmworkers. In addition to numerous presentations and publications, this project resulted in one extramural grant and the production of a 27-minute film about four cousins who travel from their Indigenous Triqui immigrant community in California to their ancestral village in Mexico for the first time to visit their ailing grandfather. This film was presented at the 2021 Portland Film Festival and won the Rising Voices Award.

5) Rietta Wagoner and Nicolas Lopez-Galvez, University of Arizona graduate students, 2018–2019

Title: Heat Exposure and Kidney Functioning in Migrant Farmworkers in the Arizona–Sonora Border Region

Chronic kidney disease of undetermined cause is an epidemic that is disproportionately affecting young laborers in warm regions throughout the world. However, no studies have evaluated kidney function in migrant farmworkers in the Arizona–Sonora border region. This study evaluated environmental and occupational factors that influence kidney function in southern Arizona and assess kidney function in migrant farmworkers via urinalysis and questionnaires regarding demographics, employment, and lifestyle. The objective of this study was to gain a better understanding of the association between occupational risk factors and kidney function in migrant farmworkers in the U.S.–Mexico border region. The project generated preliminary data that facilitated additional grant funding. Wagoner and Lopez-Galvez also gained professional experience through several presentations of the project to colleagues at the University of Arizona.

6) Farzaneh Khorsandi, Ph.D. UC Davis, 2018–2019, 2019–2020, 2020–2021

Title: Determining Agricultural ATV Safety
All-terrain vehicle (ATV) crashes are the second-leading cause of fatalities and injuries in agriculture in the U.S., with rollover incidents constituting about 85% of the deadly crashes. There are currently no practical solutions for the prevention of ATV rollover incidents in the United States; therefore, engineering controls are needed to significantly decrease the severity of injuries. Khorsandi had three Pilot/Feasibility grants. Individually, these projects 1) experimentally evaluated the performance of several crush protection devices in agricultural ATV rollover accidents (Figure 5), 2) investigated the ability of youth operators to reach agricultural ATV controls, and 3) developed required infrastructures (Autonomous ATV, outrigger, and terrain) for simulating agricultural ATV rollover incidents. These projects enabled the collection of critical preliminary data resulting in the inclusion of this work in the Children's Center competitive renewal and as part of the current WCAHS proposal as a core research project.

7) Adrianne Keeney, Ph.D., San Diego State University, 2020–2021
Title: Understanding COVID-19 Testing and Vaccine Access for Daytime Farmworkers in Imperial County
Among COVID-19 mortality, farmworkers are at an increased risk of contracting and dying from COVID-19, even when other social determinants of health were controlled such as poverty, insurance, and COVID-19 language accessibility. Imperial County has the highest proportion of non-white residents in the state of California and a COVID-19 mortality rate more than double the second highest county in the state. The county's daytime labor force is particularly affected yet understudied. Commuting from Mexicali, Baja California, Mexico, the daytime farmworker population is typically in the U.S. from 2–3 a.m. to 4–6 p.m. to ensure Imperial County's food supply chain continues, yet these workers remain essentially invisible to

county vaccination efforts and are excluded from safety net programs. Researchers interviewed six daytime farmworkers that commute daily across the U.S.–Mexico border to work and six resident farmworkers that live and work in Imperial County. Researchers also collected survey data from 199 Hispanic/Latino Imperial County farmworkers. WCAHS was able to provide the local community-based organization involved in the project with outreach material and resources on COVID-19, both for distribution during this project and in their ongoing outreach work.

B.3. Competitive Revisions/Administrative Supplements

Year 6 – additional year of funding through NIOSH. See B2 for accomplishments associated with Year 6 activities.

B.4. What opportunities for training and professional development did the project provide?

Numerous training and professional development opportunities were provided to recipients of the Pilot/Feasibility grant. For example, awardees were provided opportunities to present their research and facilitated additional grant applications.

Throughout the funding cycle, 14 Pilot/Feasibility grant awardees spoke during a WCAHS seminar or research symposium. These presentation opportunities not only fostered public speaking skills in academic settings, they also enabled awardees to interact with other investigators conducting agricultural health and safety-relevant research in different disciplines and from across the region. Awardees also participated in roundtable discussions and poster presentations at the 2018 WCAHS research symposium.

WCAHS also provided select awardees grant writing support. Funded investigators submitted 36 external grant proposals based on their WCAHS-funded findings, and 11 were funded. Grant writing support facilitated the first NIOSH grant submission on behalf of Monica Cooper, Ph.D., Kathryn Conlon, Ph.D., and Farzaneh Khorsandi, Ph.D. Dr. Cooper's pilot work on sexual harassment and its impact on the workplace environment, Dr. Conlon's work on wildfire smoke exposure, and Dr. Khorsandi's research on ATV safety all represent critical safety issues in agriculture and topics of emerging importance for NIOSH. Dr. Cooper's proposal was not funded; however, her research and sexual harassment prevention activities continue with industry partners. Dr. Conlon's proposal is being revised for resubmission. While her R21 proposal was not funded, Dr. Khorsandi now has a core research project in the NIOSH-funded Children's Center and a core research project in WCAHS' current submission.

B.5. How did you disseminate the results to communities of interest?

Results from each of the funded project have been disseminated via publications, presentations, community outreach, and videos.

For example, Pilot/Feasibility grant recipients published a total of 15 academic publications. Popular publications also resulted from awardees' research. For example,

Hobbs, M., Klachky, E., & Cooper, M. (2020). Job satisfaction assessments of agricultural workers help employers improve the work environment and reduce turnover. *California Agriculture*, *74*(1), 30-39.

- Hamilton, E. R., Patler, C. C., & Hale, J. M. (2019). Growing up without status: The integration of children in mixed-status families. *Sociology Compass*, *13*(6), e12695.

- D'Evelyn, S. M., Vogel, C. F. A., Bein, K. J., Lara, B., Laing, E. A., Abarca, R. A., ... & Pinkerton, K. E. (2021). Differential inflammatory potential of particulate matter (PM) size fractions from imperial valley, CA. *Atmospheric Environment*, *244*, 117992.

In addition to the 14 Pilot/Feasibility grant awardees presenting at WCAHS-sponsored symposia and seminars, awardees presented over 100 presentations total at major conferences in their respective fields.

The overall aim of the WCAHS is to support research that can be translated into actionable steps to improve farmworker health and safety in Arizona, California, Hawaii, and Nevada.

The research conducted by Seth Holmes resulted in the production of a 27-minute film about four cousins who travel from their Indigenous Triqui immigrant community in California to their ancestral village in Mexico for the first time to visit their ailing grandfather. This film was presented at the 2021 Portland Film Festival and won the Rising Voices Award.

B.6 - What do you plan to do during the next reporting period to accomplish the goals?
Not applicable. The funding period is now complete.

C. PRODUCTS

C.1. Publications, conference papers, and presentations

Peer-reviewed Publications

Carrasco H, Messac L, and Holmes SM. 2019. Misrecognition and Critical Consciousness-An 18-Month-Old Boy with Pneumonia and Chronic Malnutrition. The New England Journal of Medicine, 380(25): 2385-2389. doi:10.1056/nejmp1902028

Castañeda AR, Pinkerton KE, Bein KJ, Magaña-Méndez A, Yang HT, Ashwood P, Vogel CFA. 2018. Ambient particulate matter activates the aryl hydrocarbon receptor in dendritic cells and enhances Th17 polarization. Toxicology Letters. 292:85-96. https://doi.org/10.1016/j.toxlet.2018.04.020

Castañeda AR, Vogel CFA, Bein KJ, Hughes HK, Smiley-Jewell S, Pinkerton KE. 2018. Ambient particulate matter enhances the pulmonary allergic immune response to house dust mite in a BALB/c mouse model by augmenting Th2- and Th17-immune responses. Physiological Reports. 6(18): e13827. doi: 10.14814/phy2.13827

D'Evelyn SM, Vogel CFA, Bein KJ, Lara B, Laing EA, Abarca RA, Zhang Q, Li L, Li J, Nguyen TB, Pinkerton KE. 2021. Differential inflammatory potential of particulate matter (PM) size fractions from imperial valley, CA. Atmospheric Environment, 244: 117992. https://doi.org/10.1016/j.atmosenv.2020.117992

Hamilton ER, Hale, JM and Savinar R. 2019. Immigrant legal status and health: legal status disparities in chronic conditions and musculoskeletal pain among Mexican-born farm workers in the United States. Demography, 56(1): 1-24. doi: 10.1007/s13524-018-0746-8

Hamilton ER and Hale JM. 2016. Changes in the transnational family structures of Mexican farm workers in the era of border militarization. Demography, 53(5): 1429-1451. doi: 10.1007/s13524-016-0505-7

Hamilton ER, Patler C, and Hale JM. 2019. Growing up without status: The integration of children in mixed-status families. Sociology Compass, 13(6): p.e12695. https://doi.org/10.1111/soc4.12695

Hobbs M, Klatchky E, Cooper M. 2020. Job satisfaction assessments of agricultural workers help employers improve the work environment and reduce turnover. California Agriculture, 74(1): 30-39. doi:10.3733/ca.2020a0002

Hobbs M, Herrero T, Klatchky E, Cooper M. 2020. Leveraging pay and benefits as workforce retention strategies: insights from a case study of Napa vineyard workers. Catalyst: Discovery into Practice, 4(1): 33-38. doi: 10.5344/catalyst.2020.19005

Holmes SM. 2018. Marking Pre-emptive Suspects: Migrant Bodies and the Biopolitics of Exclusion. Latin American Perspectives. 45(6):30-36. https://doi.org/10.1177/0094582X17699915

Mack S, Shin J, Ahn Y, Castaneda AR, Peake J, Fulgar C, Zhang J, Cho YH, Pinkerton, KE. 2019. Age-dependent pulmonary reactivity to house dust mite allergen: a model of adult-onset asthma? American Journal of Physiology-Lung Cellular and Molecular Physiology, 316(5): L757-L763. https://doi.org/10.1152/ajplung.00468.2018

Mitchell D, Moyce S, Udaltsova I, Schenker M. 2019. The Expanding Burden of Acute Kidney Injury in California: Impact of the Epidemic of Diabetes on Kidney Injury Hospital Admissions. Nephrology Nursing Journal, 46(6): 629-640.

Pathman D. 2019. Are bias, harassment and discrimination by physician-peers a reason why some physicians leave rural communities? Invited commentary. JAMA Network Open; 2(10):e191350. doi:10.1001/jamanetworkopen.2019.13540

Seymour CK, Griffin C, Holmes SM and Martinez C. 2018. Structural differential–a 32-year-old man with persistent wrist pain. New England Journal of Medicine, 379(25), 2385-8. doi: 10.1056/NEJMp1811574

Zhang J, Fulgar CC, Mar T, Young DE, Zhang Q, Bein KJ, Cui L, Castañeda A, Vogel CFA, Sun X, Li W, Smiley-Jewell S, Zhang Z, Pinkerton KE. 2018. TH17-Induced Neutrophils Enhance the Pulmonary Allergic Response Following BALB/c Exposure to House Dust Mite Allergen and Fine Particulate Matter from California and China. Toxicological Sciences. 164(2): 627-643. https://doi.org/10.1093/toxsci/kfy127

Popular Publications

Caroll L. October 28, 2019. Female and minority health professionals face discrimination from rural colleagues. Retrieved January 5, 2022, from https://www.reuters.com/article/us-health-physicians-harassment/female-and-minority-health-professionals-face-discrimination-from-rural-colleagues-idUSKBN1X725F

Colwell S. February 10, 2020. 20 Miles Away. A World Apart. Retrieved January 5, 2022, from https://magazine.ucdavis.edu/20-miles-away/

Colwell S. July 15, 2020. Bringing an outside farming community into the UC Davis family. Retrieved January 5, 2022, from https://publicengagement.ucdavis.edu/stories/knights-landing-part-one

Colwell S. August 19, 2020. UC Davis groups work with local citizens to improve quality of life. Retrieved January 5, 2022, from https://publicengagement.ucdavis.edu/stories/knights-landing-part-two

Esquetini A. May 19, 2019. UC Davis student receives $15,000 to conduct community service project. Retrieved January 5, 2022, from https://theaggie.org/2019/05/19/uc-davis-student-receives-15000-to-conduct-community-service-project/

Frellick M. October 25, 2019. Enemy within intensifying rural clinician shortages? Retrieved January 5, 2022, from https://www.medscape.com/viewarticle/920433

Kelty S., Aranda A. October 12, 2018. Knights Landing Environmental Health Project: Two Years of Responsive Community Health. Retrieved January 5, 2002, from https://www.researchamerica.org/blog/knights-landing-environmental-health-project-two-years-responsive-community-health

Mack S. October 17, 2017. The Disappearing Salton Sea and Poor Air Quality in Imperial Valley Farm Communities: Small Grants, Big Impacts Series. Retrieved January 5, 2022, from https://aghealth.ucdavis.edu/news/disappearing-salton-sea-how-it-may-affect-air-quality-farming-communities-imperial-valley

UC Davis Global Affairs. July 28, 2020. Global Aggies: Addressing Food Insecurity, One Community at a Time. Retrieved January 5, 2022, from https://globalaffairs.ucdavis.edu/news/global-aggies-addressing-food-insecurity-one-community-time

C.2. Website(s) or other Internet site(s) – include URL(s)

Pilot/Feasibility Program: https://aghealth.ucdavis.edu/funding/small-grant-program

C.3. Technologies or techniques
Not applicable.

C.4. Inventions, patent applications, and/or licenses
Not applicable.

C.5. Other products and resource sharing

D. PARTICIPANTS

D.1. What individuals have worked on the project? Please include calendar, academic, and summer months.

Commons ID	S/K	Name	Degrees(s)	Role	Cal	Aca	Sum	Foreign	Country	SS
		Ahsan, TM Abir		GSR	3.13					
		Chowdhury, Milon		Postdoc	2.1					
		Riden, Heather E.		Acad Prg Mgt Ofcr 3 & 4	5.19					
		Simmons, Christopher W.		Researcher	0.22					

D.2 Personnel updates

N.A.

E. IMPACT

E.1 - What is the impact on the development of human resources, if applicable?

N.A.

E.2 - What is the impact the Public Health Relevance and Impact? The investigator should address how the findings of the project relate beyond the immediate study to improved practices, prevention or intervention techniques, legislation, policy, or use of technology in public health.

From 2016–2022, WCAHS funded a total of 54 Pilot/Feasibility grants, with four conducted in Arizona, 48 in California, one in Hawaii, and one in Nevada. The investigators funded highlight our track record of successfully reaching graduate students and cooperative extension specialists, as well as attracting established investigators, to explore topics related to agricultural health and safety. Many of the grants funded had aims and outcomes that could be applied broadly to agricultural in the western U.S. and beyond, such as youth operating ATVs, Valley fever (*coccidioidomycosis*), mental health, and wildfire smoke exposure. Pilot/Feasibility Program outputs include 15 publications and 110 presentations. Funded investigators submitted 36 external grant proposals based on their WCAHS-funded findings, and 11 were funded.

F. CHANGES

F.1 – Changes in approach and reasons for change, including changes that have a significant impact on expenditures

N.A.

F.2 - Actual or anticipated challenges or delays and actions or plans to resolve them

Not applicable

F.3 - Significant changes to human subjects, vertebrate animals, biohazards, and/or select agents
Not applicable

G. Special Reporting Requirements

G.1 Special Notice of Award Terms and Funding Opportunities Announcement Reporting Requirements
N.A.

G.2 Responsible Conduct of Research
N.A.

G.3 Mentor's Research Report or Sponsor Comments

N.A.

G.4 Human Subjects
G.4.a Does the project involve human subjects?
N.A.

G.4.b Inclusion Enrollment Data
N.A.

G.4.c ClinicalTrials.gov
N.A.

Does this project include one or more applicable clinical trials that must be registered in ClinicalTrials.gov under FDAAA?

G.5 Human Subject Education Requirement
Are there personnel on this project who are newly involved in the design or conduct of human subject's research?
N.A.

G.6 Human Embryonic Stem Cells (HESCS)
Does this project involve human embryonic stem cells (only hESC lines listed as approved in the NIH Registry may be used in NIH funded research)?
N.A.

G.7 Vertebrate Animals
Does this project involve vertebrate animals?
N.A.

G.8 Project/Performance Sites
University of California, Davis and Pilot/Feasibility awardee sites

G.9 Foreign Component
N.A.

G.10 Estimated Unobligated Balance

G.10.a Is it anticipated that an estimated unobligated balance (including prior year carryover) will be greater than 25% of the current year's total approved budget?

N.A.

G.11 Program Income
Is program income anticipated during the next budget period?

No

G.12 F&A Costs
Is there a change in performance sites that will affect F&A costs?
No

I. OUTCOMES

I. Provide a concise summary of the outcomes or findings of the award, written for the general public in clear and comprehensible language, without including any proprietary, confidential information or trade secrets

Note: project outcome information will be made public in NIH RePORTER

From 2016–2022, WCAHS at the University of California, Davis invested over $700,000 of center funds in research projects. The Pilot/Feasibility Program served as a principal vehicle to (1) support short-term research projects with a high likelihood of leading to further funding from extramural sources; (2) provide funding for investigators and graduate students new to the center; and (3) facilitate the exploration of new and innovative directions with the potential to advance agricultural health and safety.

The Pilot/Feasibility Program funded research that addressed agricultural health and safety in Arizona, California, Hawaii, and Nevada. Applications on a wide range of topics were encouraged. Pilot/Feasibility grants were awarded to graduate students and postdoctoral scholars up to $10,000 and faculty were able request up to $30,000. When excess funds were available, typically carryover from the previous budget year or unallocated emerging issues funds, the amount of funds available for Pilot/Feasibility grants increased and the center was able to fund more than the typical four projects. The Piot/Feasibility Program garnered increased visibility during this funding cycle with 12 submissions in 2016–2017, increasing to 39 applications in 2020–2021. In total, 118 proposal submissions were received from 2016–2022 and funded projects covered a wide range of topics utilizing basic science research methods to those qualitative in nature. For example, projects focused on ATV safety, occupational health and injury surveillance of agricultural workers, and the effects of air quality on farmworker productivity.

From 2016–2022, WCAHS funded a total of 54 Pilot/Feasibility grants, with four conducted in Arizona, 48 in California, one in Hawaii, and one in Nevada. The investigators funded highlight our track record of successfully reaching graduate students and cooperative extension specialists, as well as attracting established investigators, to explore topics related to agricultural health and safety. Many of the grants funded had aims and outcomes that could be applied broadly to agricultural in the western U.S. and beyond, such as youth operating ATVs, Valley fever (coccidioidomycosis), mental health, and wildfire smoke exposure. Pilot/Feasibility Program outputs include 15 publications and 110 presentations. Funded investigators submitted 36 external grant proposals based on their WCAHS-funded findings, and 11 were funded.

Western Center for Agricultural Health and Safety

Kent E. Pinkerton, Ph.D. and Keith Bein, Ph.D.

Project 1: Differential characterization of air pollutant emissions and associated toxicity from common agricultural practices in the San Joaquin Valley

B. ACCOMPLISHMENTS

B.1. What are the major goals of the project?

California agriculture is a $46 billion dollar industry, making California the most agriculturally productive state in the nation with combined commodities accounting for nearly 12% of US total. Over two-thirds of the country's fruits and nuts and over one-third of the country's vegetables are grown in California. More than 50% of this cropland is concentrated in the San Joaquin Valley (SJV), which only accounts for 17.5% of the state's total land area, making it the most intensely farmed region in the US. As a result, the SJV houses the largest population of farmworkers in the nation, and approximately 86% of these workers are employed in fruit, nut, and vegetable production, which are labor intensive crops.

The top six most polluted counties in the US in terms of year-round exposure to particulate matter (PM) are among the eight counties constituting the SJV, and the entire region fails all three American Lung Association tests for people at risk from exposure to short-term and year-round PM and ozone. In combination with the product distribution and transportation infrastructure, high photochemical processing, unique topography and prevailing meteorology, the intensive dry farming practices of the SJV explain these statistics. Although difficult to estimate, models suggest that agricultural practices account for over 50% of the ambient PM levels in the SJV.

There is a vast epidemiological and toxicological literature demonstrating strong associations and causal relationships between exposure to PM and various metrics of adverse pulmonary, cardiovascular, and neurological health effects. SJV farmworkers represent an especially susceptible population given a confluence of exposure to multiple known co-stressors including heat, poor working conditions, and adverse socio-economic circumstances. Therefore, it is of great importance to understand the toxicity of agricultural related emissions in order to protect and improve farmworker health through education, translation, and outreach. A key research gap is a quantitative differential assessment of the agricultural practices that pose the greatest risks in terms of exposure to PM emissions, how these emissions are toxic and which populations are most susceptible. We **hypothesize that PM emissions associated with different agricultural practices that SJV farmworkers are routinely exposed to for sustained periods will *(i)* differ in physical and chemical composition, *(ii)* elicit differential toxicological responses, and *(iii)* be toxic in different ways including gender specific differences.** To test this hypothesis, the following specific aims are explored:

Aim 1: Perform intensive field sampling and measurement campaigns at three distinct sites in the SJV dominated by different labor-intensive crops and collect size-segregated PM samples for specific agricultural practices or activities throughout the farm season corresponding to high farmworker presence, as well as provide a detailed physical and chemical characterization of the targeted practices. Selection of sampling sites and targeted practices will proceed through a novel approach combining statistical analysis of existing census data with community engaged feedback via creation of a community stakeholder advisory committee.

Aim 2: Provide detailed toxicological characterization of PM samples collected in Aim 1 using a suite of different pulmonary endpoints. All PM samples will be analyzed through *in vivo* screening to select specific samples from each site for detailed in vivo toxicological inter-comparison.

Aim 3: Based upon our results, we will develop in conjunction with the center's outreach team on recommendations and "best practices" for dissemination of our findings with activities targeted to farmworker communities and advise advocacy organizations, industry groups, and regulatory agencies on the differential toxicity of specific agricultural practices.

The goal of this research is to establish more effective strategies for managing exposure, mitigating exposure risks, heightening awareness of protective measures and regulating air quality to protect and improve farmworker health. In addition, we aim to provide a framework for making practice-specific mitigation recommendations based on differential assessment of air pollutant emissions and their associated toxicity.

B.2. What did you accomplish under these goals?

Over the past six years, Project 1 has been engaged in research in the SJV and has also expanded to include the agriculturally dominant regions of the Central and Imperial Valleys of California. Total study sites where the Aerosol Sampling and Measurement Platform (ASAMP) has been deployed include Davis, Sacramento, Fresno, Parlier, Five Points, Tulare, Taft, El Centro, and Calipatria, CA. This regional expansion of our research has permitted more in-depth, diverse and inclusive investigation of the relative toxicity of size-segregated PM including: *(i)* specific sources of PM common to urban and agricultural environments, *(ii)* the nature of urban background and agriculturally based PM mixtures and *(iii)* source- and activity-oriented agricultural PM specific to unique size fractions, i.e., ultrafine ($PM_{0.1}$), submicron fine ($PM_{1-0.1}$), supermicron fine ($PM_{2.5-1}$) and coarse ($PM_{10-2.5}$). Our studies have implemented the use of cellular markers of inflammation and reactivity in cell culture systems and an animal model of healthy and allergic mice coupled to comprehensive chemical characterization of the PM samples.

We have sought to establish the most robust and scientifically sound methods for *(i)* extracting PM from the collection substrates prior to toxicological testing, *(ii)* administering extracted PM for *in vitro* and *in vivo* studies, and *(iii)* providing a full chemical characterization of all PM samples used. Research related to and supported by this project has resulted in over 70 peer-reviewed publications, with some studies integrating climate and wildfire PM. As a natural extension of the research, we aim to continue through the renewal of WCAHS.

Our accomplishments over the past six years are listed under the following categories: **1**) Air quality sampling and measurement systems and field sampling; **2-4**) PM effects based on chemical composition, size, source, dose, and time lag; **5**) PM effects on allergic sensitization and challenge; **6**) outreach, community interactions, student, and education activities; and **7**) health implications of wildfires and climate change in agriculture.

1) Air quality sampling, measurement systems, and field sampling campaigns

Successfully engineered and implemented the ASAMP and associated sampling algorithms for conditionally sampling size-segregated PM based on real-time measurements of particle size distribution, particle mass concentration, meteorological variables, and select gas phase species. This system has been deployed on a high school campus in California's Imperial Valley for almost three years now and collected over 60 different PM samples according to size (D_p < 0.17 □m, 0.17 < D_p 1 □m, 1 < D_p < 2.5 □m, season (fall, winter, spring, and summer), time of day (00:00-06:00, 06:00-12:00, 12:00-18:00, and 18:00-24:00), and wind direction (330-30°, 30-90°, 90-150°, 150-210°, 210-270°, and 270-330°). A large cohort of these samples have been chemically and toxicologically characterized using standard analytical techniques, *in vitro* cellular bioassays, and *in vivo* animal testing.

We successfully engineered and implemented the Rapid Response Mobile Research Unit (2RMRU) for *in situ* and proximity sampling of active wildfires. It is a fully contained, self-powered mobile research laboratory for rapid deployment to active wildfires to measure and sample particle and gas phase emissions. PM and

gas samples are characterized offline while real-time measurements include particle size distribution, PM mass concentration, and combustion gas concentrations. Integrated electric vehicles (EVs) are sequentially cycled between powering the equipment and recharging, providing a continuous power source. The EVs and all associated systems are contained on a two-car open hauler easily towed by a ¾ ton truck. The 2RMRU has been deployed throughout the 2017, 2018, and 2020 California wildfire seasons. Over 20 different PM samples have been collected from several wildfires, including the 2017 Northern California Firestorm in Napa and Sonoma counties, the 2018 Carr Fire in Redding, the 2018 Mendocino Complex Fire, the 2018 Camp Fire in Paradise, and the 2020 Lightning Complex wildfires. Several of these samples have been chemically and toxicologically characterized using various analytical techniques and *in vitro* cellular bioassays. Work with these samples is ongoing and will continue into the next funding cycle of the WCAHS.

Field sampling efforts that have been completed over the past 6+ years using the ASAMP, 2RMRU, and other facilities available to us, such as the Caldecott Tunnel Exposure Facility in Oakland, California Air Resources Board building in downtown Sacramento, Kearney Agriculture and Research Extension Center in Parlier, Buena Vista Aquatic Recreation Area in Taft, UC Extension Center in Fresno, Center for Health & the Environment in Davis, and Calipatria School Board facilities in Calipatria, have resulted in an extensive, unmatched archive of PM samples from a multitude of environments and sources throughout the state of California that are available to us and other research groups for studying the chemico-toxicological profiles of PM as a function of particle size, source, composition, degree of atmospheric processing, region, and setting. In total, there are several hundred PM samples covering almost every region and season throughout California from urban centers like Oakland, Sacramento, and Fresno, to rural agricultural areas like Davis, Parlier, Taft, and Calipatria, as well as wildland-urban interface zones like Paradise, Santa Rosa, Redding, and Mendocino. A subset of these samples has already been chemically and toxicologically analyzed through our WCAHS research efforts, numerous samples have been gifted to other research groups in the US and internationally for complementary and collaborative research efforts, and others have been archived for future research plans.

2) PM effects based on chemical composition

Our research identified that PM sampled from agricultural regions of California contain a greater proportion of oxidized organic material, which significantly increase neutrophil numbers and elevate CXCL-1 and TNF-α protein levels compared to PM from China. These findings suggest that California $PM_{2.5}$ was associated with a greater inflammatory response compared to that of China $PM_{2.5}$. Differences could be due to higher oxidant levels in California PM. This work was published in *Toxicology Letters* (2017).

3) PM effects based on dose and time post-exposure

Time-lag experiments 4 days in duration were performed to explore the *in vivo* and *in vitro toxicity* of PM extracts. *In vivo* inflammatory lung responses were assessed in mice using a single oropharyngeal aspiration (OPA) of PM. On day 1, BAL neutrophils were significantly elevated in all PM. Histopathological scoring demonstrated alveolar and perivascular effects; however, by day 4, tissue inflammation had resolved.

In vitro PM effects in human HepG2 hepatocytes, and U937 cells were examined following 6, 24, or 48 h of exposure to PM. Luciferase reporter and quantitative polymerase chain reaction assays were used to determine *in vitro* effects on aryl hydrocarbon receptor (AhR) activation and gene transcription, respectively. Though all three PM extracts activated AhR, PMSX produced the greatest increases in AhR activation and mRNA levels of cyclooxygenase-2, cytochrome P450, interleukin (IL)-8, and interleukin (IL)-1β. These effects were thought to be due to an abundance of polycyclic aromatic hydrocarbons (PAHs) in PM. These research findings were published in *Toxicology Letters* (2020).

Effects of repeated PM exposure and time lag effects. Chemical analysis demonstrated the presence of black carbon, sulfates and polycyclic aromatic hydrocarbons (PAHs) to be associated with increased neutrophil number and enhanced alveolar/ bronchiolar inflammation on post-exposure days 1 and 4. On day

4, PMSX-exposed mice also exhibited significant increases in interleukin-1 beta, tumor necrosis factor-alpha, and chemokine C-X-C motif ligands-3 and -5 mRNA, and monocyte chemoattractant protein-1 protein. These findings suggest chemical composition (sulfates and PAH content) can contribute to a more intense and progressive inflammatory response with repeated PM exposure. Published in *Toxicology Letters* (2022).

4) PM effects based on size, source, and chemical composition

To determine if there are differences in the composition and biological response to Imperial County PM by size, ambient PM samples were collected from a sampling unit stationed in the northernmost part of the valley, South of the Salton Sea. **Ultrafine, fine, and coarse PM** samples were collected and extracted separately. Chemical composition of each size fraction was obtained after extraction by using several analytical techniques, and biological response was measured by exposing a cell line of macrophages to particles and quantifying subsequent gene expression. Biological measurements demonstrated that coarse PM induced an inflammatory response in macrophages measured in increases of inflammatory markers IL-1ß, IL-6, IL-8 and CXCL2 expression, whereas ultrafine and fine PM only demonstrated significant increases in expression of CYP1a1. These differential responses were due not only to particle size, but to the distinct chemical profiles of each size faction as well. Community groups in Imperial Valley have already completed several projects to learn more about local air quality, giving residents access to data that provides real-time levels of PM2.5 and PM10 as well as recommendations on health-based practices dependent on the current AQI (air quality index). However, to date there is no information on the composition or toxicity of ambient PM from the region. The data presented here could provide more definitive information on the toxicity of PM by size, and further inform the community on local air quality. This research was published in *Atmospheric Environment* (2021).

We conducted a study/review on the importance of **bioaerosols** in addition to PM. While air pollution in total includes gaseous, solid, and liquid constituents, PM may also contain anthropogenic, geogenic, and/or biogenic fractions. We reviewed the extent of particles originating from microbial, fungal, animal, or plant sources, also called bioaerosols. Understanding particle and exposure characteristics that most influence deposition and clearance processes in the respiratory tract were also examined to include particle size, shape, charge, and composition. Research on the co-exposure of PM and bioaerosols as dual stressors to the respiratory system could aid in more thoroughly understanding the etiology of respiratory injury and disease. This research was published in *Comprehensive Physiology* (2019) in partial completion of the Ph.D. degree for graduate student Savannah D'Evelyn.

Wildfire PM chemical impact: To examine the impact of wildfire smoke on fertility, timing of birth, and pregnancy loss, a unique case-control study on birth outcomes in rhesus macaques (*Macaca mulatta*) was conducted at the California National Primate Research Center under the auspices of Project 1. All female monkeys in the study were maintained in outdoor fields during a period of elevated ambient wildfire smoke from November 8–22, 2018. In addition to ambient air quality evaluations, the effects on fertility, timing to birth, and pregnancy loss were documented. Archival records of approximately 5,000 conceptions from the previous nine years served as control data. During the Camp Fire, ambient fine particulate ($PM_{2.5}$) levels exceeded the 24-hr National Ambient Air Quality Standard (35 $\mu g/m^3$) of the United States Environmental Protection Agency, reaching levels as high as 185 $\mu g/m^3$. A statistically significant association was observed between birth loss and the 2018–2019 CNPRC breeding season. As this wildfire event occurred during various stages of early pregnancy, an association can be inferred between early gestational exposure and increased risk of pregnancy loss. This research was published in *Reproductive Toxicology* (2021).

Additionally, PM samples collected during the 2017 Northern California Firestorm that ravaged Napa and Sonoma Counties were studied using a battery of *in vitro* assays on bone marrow-derived macrophages. Results showed that exposure to wildfire PM activated aryl hydrocarbon receptor (AhR) and NF-kB signaling and significantly induced the expression of IL-22. PM samples from traffic related air pollution (TRAP) collected from the Caldecott Tunnel Exposure Facility were also included in the study and showed similar results but were significantly less bioactive than the wildfire PM. A comprehensive differential chemical

characterization of the PM samples showed the wildfire PM to be significantly enhanced in several trace elements relative to TRAP, like Pb and Br, and that the organic content of the samples was substantially different. From these data, it was hypothesized that the difference in toxicity is most likely a result of differences in chemical composition, including the potential presence of polyhalogenated aromatic hydrocarbons in the wildfire PM due to combustion of the built environment in large residential areas of Santa Rosa during the fires. These results have been published in *Frontiers in Toxicology* (2022).

Several additional studies on the chemical and toxicological properties of wildfire PM collected throughout the 2017–2020 California wildfire seasons via our 2RMRU are currently ongoing. These studies were partially funded by the WCAHS Pilot/Feasbility Program, as well as several other centers on the UC Davis campus.

5) PM effects on allergic sensitization and challenge

Five seminal studies completed from 2016 to 2022 established the importance of PM on allergic sensitization and allergen challenge in mice using house dust mite (HDM). Five graduate students were involved in these studies from immunology, molecular, cellular, and integrative physiology in partial fulfillment of their doctoral degrees. Their research was published in the *Journal of Toxicology and Environmental Health* (2017), *Toxicology Letters* (2018), *Physiological Reports* (2018), *Toxicological Sciences* (2018), and the *American Journal of Physiology: Lung Cellular and Molecular Physiology* (2019), *Atmospheric Environment* (2019), *Toxicology Letters* (2020), *Reproductive Toxicology* (2021), *PLoS ONE* (2022), *Toxicologic Pathology* (2022).

Aryl hydrocarbon receptor (AhR) in PM-mediated activation of dendritic cells (DCs) and Th17-immune responses were confirmed using *in vitro* techniques. Bone marrow (BM)-derived macrophages and DCs from C57BL/6 wildtype or AhR knockout (AhR−/−) mice were treated with PM. Th17 differentiation was assessed via co-cultures of wildtype or AhR−/− BMDCs with autologous naive T cells. PM2.5 significantly induced AhR DNA binding activity to dioxin responsive elements (DRE) and expression of the AhR repressor (AhRR), cytochrome P450 (CYP) 1A1, and CYP1B1, indicating activation of the AhR. In activated (OVA sensitized) BMDCs, PM2.5 induced interleukin (IL)-1β, CD80, CD86, and MHC class II, suggesting enhanced DC activation, co-stimulation, and antigen presentation; responses that were abolished in AhR deficient DCs. DC-T cell co-cultures treated with PM and lipopolysaccharide (LPS) led to elevated IL-17A and IL-22 expression at the mRNA level, which is mediated by the AhR. PM-treated DCs were essential in endowing T cells with a Th17-phenotype, which was associated with enhanced expression of MHC class II and cyclooxygenase (COX)-2. In conclusion, PM enhances DC activation that primes naive T cell differentiation towards a Th17-like phenotype in an AhR-dependent manner (Tox. Letters 2018).

Augmentation of the Th2- and Th17-immune responses due PM: Studies show that PM has adjuvant-like properties that enhance the allergic inflammatory response; however, the mechanisms through which PM enhances these processes remain elusive. Gene expression was analyzed in whole lung to characterize immune markers of inflammation: cytokines, chemokines, antioxidant enzymes, and transcription factors. Cytokine and chemokine protein levels were quantified in whole lung to confirm gene expression patterns. Compared to HDM-only sensitization, exposure to PM during HDM sensitization led to significant immune cell recruitment into the airway sub-epithelium, IgE gene expression, mucosubstance production, and Th2-associated cytokine expression. Gene expression profiles suggest that polycyclic aromatic hydrocarbon (PAH) content in PM activated the aryl hydrocarbon receptor (AhR) and enhanced Th17-responses in the mice that received HDM and PM compared to mice that received HDM only. These findings suggest PM augments allergic sensitization through the enhancement of Th2-mediated inflammation and that AhR activation by PAHs in PM promotes Th17-immune responses. Results were published in JTEH (2017) and Physiol. Rep. (2018).

Further studies demonstrated the importance of TH17-induced neutrophils to enhance the pulmonary allergic response in mice following exposure to HDM. This enhanced exacerbation due to metals and oxidized organic content of PM (*Tox Sci* 2018).

Established a model of **adult-onset asthma** in female mice aged 9 months, compared to mice 3 months of age. Adult-onset asthma is well-established as a condition prevalent in California's Central Valley. Our studies found 9-mo-old HDM-exposed mice had significant airway hyper-responsiveness compared with age-matched controls. These HDM-exposed mice also had 1) statistically significant increases in tissue bronchiolitis, perivasculitis, and BALF neutrophilia relative to their younger counterparts and 2) significantly increased extent of immunostaining compared with all other groups. This study presents a potential model for adult-onset asthma, focusing specifically on the atopic, peri-menopausal female phenotype. These findings suggest that lung function declines with age and that the inflammatory profile of this adult subgroup is a mixed, rather than a simple, atopic, Th2 response. This model may enhance our understanding of how age influences the development of asthmatic-like symptoms in older subgroups. This research was published in the *American Journal of Physiology: Lung Cellular and Molecular Physiology* (2019).

6) Outreach, community interactions, student, and educational activities

We have worked closely with the Outreach Core at WCAHS to create videos and presentations as part of worker training in the field. These have included dozens of presentations on air quality, health effects of PM, and susceptibility of agricultural workers with pre-existing cardiopulmonary conditions.

We established a working relationship with the advocacy organization Comite Civico del Valle (CCV) of Imperial Valley to discuss issues of air quality facing the region, which is known for raising cattle and winter crops. We conducted meetings with high school students, teachers, and administrators at Calipatria and El Centro High Schools to discuss their involvement in a community-based project on air quality. They were highly enthusiastic and provided to us a location on the high school campus of Calipatria in the operation of our PM field station. Particles were collected over a three-year period at this site with the assistance of the students in the operation of the field station and training in the installation of filters and the proper storage over the course of the study. These filters were sent to UC Davis for toxicological and chemical studies.

In the summers of 2018 and 2019, Imperial Valley students participated in two, one-week-long, highly successful summer research programs at UC Davis. Six students in 2018 and nine students in 2019 came on full scholarships. The travel and lodging for these students were covered completely by a Rapid Response grant written by graduate student Savannah D'Evelyn. During these summer research programs, the students conducted research on the PM samples they had assisted in collecting form the Imperial Valley. During the week, they attended classes, learned laboratory techniques, and worked with staff, graduate students, and faculty from WCAHS. The students presented their findings at the end of their stay at UC Davis. After returning home, they also presented their findings in school and to the community. Of the 15 students who participated in this program, ten are now in college and two of these students are attending UC Davis. We continue to have a strong relationship with Imperial Valley and are actively seeking additional joint research projects.

Despite COVID-19 limitations, we continue to work with high school and college students. In the summer of 2020, two UC Davis undergraduate students in the Public Health Scholars program conducted research on outreach and evaluation guidelines for COVID-19 safety in agriculture and face mask use. This research continued into the following year to create safety training and outreach to the Punjabi agricultural communities of Yuba and Fresno Counties. This research was done in conjunction with an MPH student at UC Berkeley, and a manuscript on this research will be submitted in early 2023.

7) Health implications of wildfires and climate change in agriculture: training materials and publications

Project 1 has been actively involved with the impact of climate and wildfires on agriculture. We have been successful in *(1)* sampling air pollution throughout the Central Valley and Northern California and *(2)* the creation of a checklist and guidelines for health and safety training of workers in the agricultural setting. Wide dissemination of these materials to agricultural stakeholders in California has been accomplished through extensive mailing to agricultural organizations, advocacy groups, and state agencies. In a recent study, we examined how wildfire smoke exposure may impact health and safety in the agricultural workplace. Semi-structured interviews were conducted with agricultural employers and focus group discussions were held with farmworkers in three regions of California: Central Valley, Salinas Valley, and Imperial Valley. Adapting health promotion and workplace safety strategies to meet the multiple vulnerabilities and diverse needs of farmworkers is critical to successful implementation of workplace protection and safety measures. Given limited familiarity with the topic, wildfire smoke exposure resources are needed to assist employers and supervisors in their compliance with a new wildfire smoke safety regulation in California. To the best of our knowledge, this is the first study to explore agricultural employer and farmworker perceptions of the health and safety impacts of wildfire smoke and workplace exposure. These findings were published in the *Journal of Agromedicine* (2020).

In collaboration with the WCAHS Outreach Core and through funding from NIOSH, we were able to create a brochure titled “Extreme Weather Events: Perspectives and Safety Impacts in Agriculture” based on interviews and focus group discussions to determine how weather extremes have affected the work, health, and safety of agricultural employers and farmworkers. A total of 16 interviews were completed with agricultural employers, and nine focus groups were conducted with over 70 farmworkers in Monterey, Fresno, Riverside, and Imperial Counties. The brochure contains the replies of the employers and the farmworkers on the topics of heat, rain, drought, agricultural dust, wildfires, and night work. This survey provided critical insight into future research and opportunities to enhance health and safety practices in the agricultural workplace through improved awareness of the experiences of others.

B.3. Competitive Revisions/Administrative Supplements

Year 6 – additional year of funding through NIOSH. See B2 for accomplishments associated with Year 6 activities.

B.4. What opportunities for training and professional development did the project provide?

Numerous high school students, community members, advocacy organization staff, undergraduates, graduate students, postdoctoral scholars, academic researchers, and visiting scholars have been involved in our study over the past six years. These efforts and opportunities have provided training and professional development across various disciplines, career stages and trajectories, and sectors. For example, there has been consistent and constructive two-way exchange of information and training between UC Davis researchers conducting the study at the Calipatria High School campus and the Imperial Valley community members, including staff at Comite Civico del Valle, members of the Imperial Valley Advisory Committee, and students at Calipatria High School. Researchers were introduced to the community and granted access to community resources via our working relationship with Comite Civico del Valle. Members of the advisory committee have educated researchers about the concerns and perceptions of community members, as well as cultural sensitivities to the researcher–community relationship. Researchers have engaged Calipatria High School students and trained them on basic operation and maintenance of the ASAMP, including all sampling hardware and instrumentation. High school students have also been brought to the U.C. Davis campus during a one-week, grant-funded summer program on two separate occasions to learn basic techniques and methodologies in the extraction, preparation, chemical characterization and toxicological assessment of PM samples collected by the ASAMP. We strongly feel that participation of the students in our project not only stimulates their interest in science, but also allows them involvement in issues directly impacting their community by empowering them with the knowledge to advocate for change. This has been perhaps the greatest training and development effort of this project. Due to the pandemic, however, our efforts shifted to students at UC Davis. These have included programs in the Summer Enhancement

Program (SEP) with virtual conferences to provide lectures and laboratory sessions to undergraduates around the country in training in the cardiovascular and respiratory systems, graduate students in wildfire health effects and COVID-19 safety guidelines in the agricultural setting, as well as nationwide broadcasts with the United States Department of Agriculture and the National Academies of the Sciences, Engineering and Medicine in wildfire and COVID-19 training in the agricultural setting. We strongly feel our participation in these events has stimulated greater student interest in the sciences, helped to involve active participation in laboratory and field experiments, and has also resulted in active community and stakeholder involvement on issues directly impacting the agricultural community.

B.5. How did you disseminate the results to communities of interest?

Over the past 6 years, we have engaged in virtual and in-person community meetings, webinars, science fairs, regional and international professional scientific conferences, and expert panels on air quality, climate change, wildfires, and environmental justice in various settings including academia, state agencies, and advocacy and community organizations. We have also been actively engaged with interviews via various media outlets such as newspaper and magazine articles, radio broadcasts, news channels, blogs, podcasts, and documentaries. Furthermore, we have been active in the dissemination of training materials and checklists to advocacy groups, labor contractors, farm organizations, and the agricultural industry. For example, wildfire and COVID-19 training materials have been disseminated via mailing to hundreds of farms and organizations throughout the state of California. These training materials have been used in training efforts throughout California. A list of media interviews is provided below.

Media Interviews

Toxic wildfire smoke raises health risks across the country, Newspaper Article, November 13, 2022, Matt Vasilogambros, The Washington Post, article link.

How much do Blue Angels flying in SF's Fleet Week cost taxpayers? Newspaper Article, October 6, 2022, Claire Hao, San Francisco Chronicle, article link.

Confronting Climate Anxiety, 4-part Series, August 8, 2022, Kat Kerlin, UC Davis News, article link

Explainer: Smoke from raging wildfires can harm health, Newspaper Article, July 21, 2022, Nancy Lapid, Reuters, article link.

Exposure to wildfire smoke altered DNA structure in monkeys, Newspaper Article, March 8, 2022, Zack Savitsky, The Mercury News, San Jose, article link.

Exercise Can Build Up Your Brain. Air Pollution May Negate Those Benefits, Newspaper Article, February 23, 2022, Keith E. Morrison, The New York Times, article link.

One Planet: The Health Impacts of Wildfires, Radio Interview, May 9, 2021, Your Call, KALW Public Media, 91.7 FM Bay Area, audio link.

Society of Toxicology TV - Episode 3, Video, March 27-31, 2021, WebsEdge/Health/Society of Toxicology, video link.

How breathing in wildfire smoke affects the body, Magazine Article, April issue, 2020, National Geographic (Sarah Gibbens and Amy McKeever), article link.

How Can Your Air Quality Be "Moderate' When Sky is Grimy Orange, Newspaper Article, September 11th, 2020, NBC4 News (Patrick Healy), article link.

Waking Up to Wildfires (Emmy-nominated documentary by Paige Bierma), Video, March 10th, 2020, PBS, YouTube, UCD Environmental Health Sciences Center, video link.

Rat Study Shows How Air Pollution Impacts Early Brain Development, Magazine Article, June 18th, 2020, Technology Networks: Neuroscience News & Research, article link.

Air Quality Impacts Early Brain Development, Website, June 17th, 2020, UC Davis News (Trina Wood), article link.

News Feature: How air pollution threatens brain health, Magazine Article, June 23rd, 2020, Proceedings of the National Academy of Sciences (Lynne Peeples), article link.

Climate crisis poses serious risks for pregnancy, investigation finds, Newspaper Article, June 18th, 2020, The Guardian, article link.

Climate Change Tied to Increased Pregnancy Risks, Analysis Finds, Newspaper Article, June 19th, 2020, Yale Environment 360, article link.

Air Quality Impacts Early Brain Development, Website, June 18th, 2020, Environmental News Network, article link.

Air Quality Impacts Early Brain Development, Magazine Article, June 17th, 2020, Scienmag, article link.

UC Davis: Air Quality Impacts Early Brain Development, Newspaper Article, June 17th, 2020, California Patch, article link.

Traffic-related air pollution may affect the developing brain, Newspaper Article, June 17th, 2020, The Medical News, article link.

Air Quality Impacts Early Brain Development, Newspaper Article, June 17th, 2020, Science Daily, article link.

Air Quality Impacts Early Brain Development, Newspaper Article, June 17th, 2020, Medical Xpress, article link.

UC Davis finds air quality affects early brain development, Newspaper Article, June 17th, 2020, Daily Democrat, article link.

Urban wildfires bring lingering worries about what's in the ash and air, Television Interview, September 11, 2018, PBS Newshour, video link.

'It's getting worse:' Climate change stokes fiery future for California, Newspaper Article, September 15, 2018, The Press Democrat, article link.

UC Davis study to focus on post-Sonoma County fire pollution, Newspaper Article, January 24, 2018, The Press Democrat, article link.

Testing Sonoma Ash and Air for Fire-Formed Pollutants, Website, January 23, 2018, U.C. Davis News in Science & Technology, article link.

Masks Make a Difference in Wildfires, Newspaper Article, November 15, 2018, U.S. News, article link.

To protect your lungs from wildfire smoke, the mask you wear matters, Newspaper Article, November 15, 2018, Los Angeles Times (Samantha Young and Ana Ibarra), article link.

B.6 - What do you plan to do during the next reporting period to accomplish the goals?
N.A.

C. PRODUCTS

C.1. Publications, conference papers, and presentations

Publications:

2022

Fang J, Silva R, Tancredi D, Pinkerton KE, Sankaran K. **In press**. Examining associations in congenital syphilis infection and socioeconomic factors between California's small-to-medium and large metro counties. *Journal of Perinatology*.

Huynh H, Upadhyay P, Lopez CH, Miyashiro MK, Van Winkle LS, Thomasy SM, Pinkerton KE. **In press**. Inhalation of Silver Silicate Nanoparticles Leads to Transient and Differential Microglial Activation in the Rodent Olfactory Bulb. *Toxicologic Pathology*.

Yichen L, Jiayin D, Tran L, Pinkerton KE, Spindel E, Nguyen T. **In press**. Vaping Aerosols from Vitamin E Acetate and Tetrahydrocannabinol Oil: Chemistry and Composition. *Chemical Research in Toxicology*.

Domanico M, Fukuto A, Tran LM, Bustamante JM, Edwards PC, Thomasy SM, Pinkerton KE, Van Winkle LS. **In press**. Cytotoxicity of 2D Engineered Nanomaterials in Pulmonary and Corneal Epithelium. *NanoImpact*.

Cosert KM, Kim S, Jalilian I, Chang M, Gates BL, Pinkerton KE, Van Winkle LS, Raghunathan VK, Leonard BC, Thomasy SM. 2022. Metallic Engineered Nanomaterials and Ocular Toxicity: A Current Perspective. *Pharmaceutics*, 14(981). https://doi.org/10.3390/pharmaceutics14050981.

Zhang C, Li W, Li X, Wan D, Mack S, Zhang J, et al. 2022. Novel aerosol treatment of airway hyper-reactivity and inflammation in a murine model of asthma with a soluble epoxide hydrolase inhibitor. *PLoS ONE* 17(4): e0266608. https://doi.org/10.1371/journal.pone.0266608

Boğana M, Kulb S, Ala B, Oktaya M, Akpinar Elçic M, Pinkerton KE, Bayram H. 2022. Effects of Desert Dust Storms and Meteorological Factors on Respiratory Diseases in Southeast Turkey. *Allergy* 77(7), 2243-2246. https://doi.org/10.1111/all.15298

Wang L, Rajavel M, Wu CW, Zhang C, Poindexter M, Fulgar C, Mar T, Singh J, Dhillon JK, Zhang JJ, Yuan Y, Abarca R, Li W, Pinkerton KE. 2022. Effects of life-stage and passive tobacco smoke exposure on pulmonary innate immunity and influenza infection in mice. Journal of Toxicology and Environmental Health, Part A, 85(11), 439-456. https://doi.org/10.1080/15287394.2022.2032518

Sadekar N, Boisleve F, Dekant W, Fryer AD, Gerberick GF, Griem P, Hickey C, Krutz NL, Lemke O, Mignatelli C, Panettieri R, Pinkerton KE, Renskers KJ, Sterchele P, Switalla S, Wolter M, Api AM. 2022. Identifying a Reference List of Respiratory Sensitizers for the Evaluation of Novel Approaches to Study

Respiratory Sensitization. *Critical Reviews in Toxicology* 51(10). https://doi.org/10.1080/10408444.2021.2024142

Wadsworth G, Riden HE, Pinkerton KE. 2022. Farmer Perceptions of Climate, Adaptation and Management of Farmworkers. *Journal of Agriculture, Food Systems and Community Development* 11(2). https://doi.org/10.5304/jafscd.2022.112.015

Yuan W, Velasquez SC, Wu CW, Fulgar CC, Zhang Q, Young DE, Bein KJ, Vogel CFA, Li W, Cui LL, Wei HY, Pinkerton KE 2022. Pulmonary health effects of wintertime particulate matter from California and China following repeated exposure and cessation. *Toxicology Letters* 354: 33-43. https://doi.org/10.1016/j.toxlet.2021.10.014

Ishihara Y, Kado SY, Bein KJ, He Y, Pouraryan AA, Urban A, Haarmann-Stemmann T, Sweeney C, Vogel CFA. 2022. Aryl hydrocarbon receptor signaling synergizes with TLR/NF-κB-signaling for induction of IL-22 through canonical and non-canonical AhR pathways. *Frontiers in Toxicology*, 3: 787360. https://doi.org/10.3389/ftox.2021.787360.

Dutta M, Weigel KM, Patten KT, Valenzuela AE, Wallis C, Bein KJ, Wexler AS, Lein PJ, Cui JY. 2022. Chronic exposure to ambient traffic-related air pollution (TRAP) alters gut microbial abundance and bile acid metabolism in a transgenic rat model of Alzheimer's disease. *Toxicology Reports*, 9: 432-444. https://doi.org/10.1016/j.toxrep.2022.03.003.

Liang N, Emami S, Patten KT, Valenzuela AE, Wallis CD, Wexler AS, Bein KJ, Lein PJ, Taha AY. 2022. Chronic exposure to traffic-related air pollution reduces lipid mediators of linoleic acid and soluble epoxide hydrolase in serum of female rats. *Environmental Toxicology and Pharmacology*, 93: 103875. https://doi.org/10.1016/j.etap.2022.103875.

Bein KJ, Wallis CD, Silverman JL, Lein PJ, Wexler AS. 2022. Emulating near-roadway exposure to traffic-related air pollution via real-time emissions from a major freeway tunnel system. *Environmental Science & Technology*, 56(11), 7083-7095. https://doi.org/10.1021/acs.est.1c07047.

Patten KT, Valenzuela AE, Wallis C, Harvey DJ, Bein KJ, Wexler AS, Gorin FA, Lein PJ. 2022. Hippocampal but not serum cytokine levels are altered by traffic-related air pollution in TgF344-AD and wildtype Fischer 344 rats in a sex- and age-dependent manner. *Frontiers in Cellular Neuroscience*, 16: 861733. https://doi.org/10.3389/fncel.2022.861733.

Badley J, Cossaboon J, Malany K, McNabb NA, Mouat JS, Parenti M, Sharifi O, Stevens NC, Thongphanh K, Xu J, Bein KJ, Van Winkle LS, Lein PJ. 2022. Forged in Fire: Environmental Health Impacts of Wildfires, Open Access Government, eBook

Mack, S.M., Wu, C-W., Zhang, C., Richard Harding, Pinkerton, K.E., 2022. Lung Anatomy and Aging. In: Janes, S.M. (Ed.), Encyclopedia of Respiratory Medicine, vol. 2. Elsevier, Academic Press, pp. 64–72. https://dx.doi.org/10.1016/B978-0-12-801238-3.11600-9.

Xu J, Qiu X, Yu G, Ly M, Yang J, Silva RM, Zhang X, Yu M, Wang Y, Hammock B, Pinkerton KE, Zhao D. 2022. Soluble epoxide hydrolase inhibitor can protect the femoral head against tobacco smoke exposure-induced osteonecrosis in spontaneously hypertensive rats. *Toxicology* 465: 153045. https://doi.org/10.1016/j.tox.2021.153045.

2021

Li Y, Burns AE, Tran LN, Abellar KA, Poindexter M, Li X, Madl AK, Pinkerton KE, Nguyen TB. 2021. Impact of e-Liquid Composition, Coil Temperature, and Puff Topography on the Aerosol Chemistry of Electronic Cigarettes. *Chemical Research in Toxicology* 34(6):1640-1654. https://doi.org/10.1021/acs.chemrestox.1c00070.

Fukuto A, Kim S, Kang J, Gates BL, Chang MW, Pinkerton KE, Van Winkle LS, Kiuchi Y, Murphy CJ, Leonard BC, Thomasy SM. 2021. Metal oxide engineered nanomaterials modulate rabbit corneal fibroblast to myofibroblast transformation. *Transl Vis Sci Technol.*10(12): 23. https://doi.org/10.1167/tvst.10.12

Sun J, Pan S, Karey E, Chen YJ, Pinkerton KE, Wilson CG, Chen CY. 2021. Secondhand smoke decreased excitability and altered action potential characteristics of cardiac vagal neurons in mice. *Frontiers in Physiology* 12:727000. https://doi.org/10.3389/fphys.2021.727000.

Willson BE, Gee NA, Willits NH, Li L, Zhang Q, Pinkerton KE, Lasley BL. 2021. Effects of the 2018 Camp Fire on Birth Outcomes in Non-human Primates: Case-Control Study. *Reproductive Toxicology* 105:128-135. https://doi.org/10.1016/j.reprotox.2021.08.005.

Tang M, Luo XS, Huang W, Pang Y, Hong Y, Chen J, Wu L, Pinkerton KE. 2021. Seasonal and areal variability in $PM_{2.5}$ poses differential degranulation and pro-inflammatory effects on RBL-2H3 cells. *Chemosphere* 279:130919. https://doi.org/10.1016/j.chemosphere.2021.130919.

Kim S, Gates BL, Chang M, Pinkerton KE, Van Winkle LS, Murphy CJ, Leonard B, Demokritou P, Thomasy SM. 2021. Transcorneal delivery of topically applied silver nanoparticles does not delay epithelial wound healing. NanoImpact 24:100352. https://doi.org/10.1016/j.impact.2021.100352

Le T, Baudel MMA, Syed A, Singhrao N, Pan S, Flores-Tamez VA, Burns AE, Man KNM, Karey E, Hong J, Hell JW, Pinkerton KE, Chen C-Y, Nieves-Cintrón M. 2021. Secondhand smoke exposure impairs ion channel function and contractility of mesenteric arteries *Function* 2(5). https://doi.org/10.1093/function/zqab041.

Tarran R, Barr RG, Benowitz NL, Bhatnagar A, Chu HW, Dalton P, Doerschuk CM, Drummond MB, Gold DR, Goniewicz ML, Gross ER, Hansel NN, Hopke PK, Kloner RA, Mikheev VB, Neczypor EW, Pinkerton KE, Postow L, Rahman I, Samet JM, Salathe M, Stoney CM, Tsao PS, Widome R, Xia t, Xiao D, Wold LE. E-Cigarettes and Cardiopulmonary Health. 2021. *Function* 2(2). https://doi.org/10.1093/function/zqab004.

Annesi-Maesano I, Forastiere F, Balmes J, Garcia E, Harkema J, Holgate S, Kelly F, Khreis H, Hoffmann B, Maesano CN, McConnell R, Peden D, Pinkerton KE, Schikowski T, Thurston G, Van Winkle LS, Carlsten C. 2021. The clear and persistent impact of air pollution on chronic respiratory diseases: a call for interventions. *European Respiratory Journal* 57:2002981. https://doi.org/10.1183/13993003.02981-2020.

Liu J, Chen S-J, Hsu S-W, Zhang J, Li J-M, Yang DC, Gu S, Pinkerton KE, Chen C-H. 2021. 3MARCKS cooperates with NKAP to activate NF-kB signaling in smoke-related lung cancer. *Theranostics* 11(9): 4122-4136. https://doi.org/10.7150/thno.53558.

Fenske RA, Pinkerton KE. 2021. Climate Change and the Amplification of Agricultural Worker Health Risks, *Journal of Agromedicine* 26(1): 15-17. https://doi.org/10.1080/1059924X.2021.1849211

D'Evelyn SM, Vogel CFA, Bein KJ, Lara B, Laing EA, Abarca RA, Zhang Q, Li L, Li J, Nguyen TB, Pinkerton KE. 2021. Differential inflammatory potential of particulate matter (PM) size fractions from Imperial Valley, CA. *Atmospheric Environment* 244:117992. https://doi.org/10.1016/j.atmosenv.2020.117992.

Patten KT, Valenzuela AE, Wallis CD, Berg EL, Silverman JL, Bein KJ, Wexler AS, Lein PJ. The effects of chronic exposure to ambient traffic-related air pollution on Alzheimer's disease phenotypes in wildtype and

genetically predisposed male and female rats. Environmental Health Perspectives, 129(5): 057005. https://doi.org/10.1289/EHP8905.

2020

Xiao Y, Yan L, Zhang M, Pinkerton KE, Cao H, Xiao Y, Li W, Li S, Wang Y, Li S, Cao Z, Wong G, Xu H, hang HT. 2020. Machine learning discovery of distinguishing laboratory features for severity classification of COVID-19 patients. *IET Cyber-Syst. Robot*. 3:31–43. https://doi.org/10.1049/csy2.12005.

Ogorodnik E, Karsai A, Wang K-H, Liu F-T, Lo SH, Pinkerton KE, Gilbert B, Haudenschild DR, Liu G-Y. 2020. Direct Observations of Silver Nanowire-Induced Frustrated Phagocytosis among NR8383 Lung Alveolar Macrophages. *The Journal of Physical Chemistry B* 124 (51): 11584-11592. https://doi.org/10.1021/acs.jpcb.0c08132.

Pham AK, Wu CW, Qiu X, Xu J, Smiley-Jewell S, Uyeminami D, Upadhyay P, Zhao D, Pinkerton KE. 2020. Differential lung inflammation and injury with tobacco smoke exposure in Wistar Kyoto and spontaneously hypertensive rats. *Inhal Toxicol.* 32(8):328-341. https://doi.org/10.1080/08958378.2020.1805052.

Riden HE, Schilli K, Pinkerton KE. 2020. Rapid Response to COVID-19 in Agriculture: A Model for Future Crises, *Journal of Agromedicine* 25(4): 392-395. https://doi.org/10.1080/1059924X.2020.1815618

Yuan W, Fulgar CC, Sun X, Vogel CFA, Wu CW, Zhang Q, Bein KJ, Young DE, Li W, Wei H, Pinkerton KE. 2020. In vivo and In vitro Inflammatory Responses to Fine Particulate Matter ($PM_{2.5}$) from China and California. Toxicology Letters 354: 33-43. https://doi.org/10.1016/j.toxlet.2020.04.010.

Li Y, Burns AE, Burke GJP, Poindexter ME, Madl AK, Pinkerton KE, Nguyen TB. 2020. Application of High-Resolution Mass Spectrometry and a Theoretical Model to the Quantification of Multifunctional Carbonyls and Organic Acids in e-Cigarette Aerosol. *Environmental Science & Technology 54*(9): 5640-5650. https://doi.org/10.1021/acs.est.9b07387.

Thurston GD, Balmes JR, Garcia E, Gilliland FD, Rice MB, Schikowski T, Van Winkle LS, Annesi-Maesano I, Burchard EG, Carlsten C, Harkema JR, Khreis H, Kleeberger SR, Kodavanti UP, London SJ, McConnell R, Peden DB, Pinkerton KE, Reibman J, White CW. 2020. Outdoor Air Pollution and New-Onset Airway Disease. An Official American Thoracic Society Workshop Report. *Ann Am Thorac Soc.* 17(4):387-398. https://doi.org/10.1513/AnnalsATS.202001-046ST.

Lu X, Zhang L, Du H, Zhang J, Li YY, Qu J, Zhang W, Wang Y, Bao S, Li Y, Wu C, Liu H, Liu D, Shao J, Peng X, Yang Y, Liu Z, Xiang Y, Zhang F, Silva RM, Pinkerton KE, Shen K, Xiao H, Xu S, Wong GWK. 2020. Chinese Pediatric Novel Coronavirus Study Team. SARS-CoV-2 Infection in Children. *N Engl J Med.* 382: 1663-1665. https://doi.org/10.1056/NEJMc2005073.

Kim S, Gates B, Leonard BC, Gragg M, Pinkerton KE, Van Winkle LS, Murphy CJ, Pyrgiotakis G, Zhang Z, Demokritou P, Thomasy SM. 2020. Engineered metal oxide nanomaterials inhibit corneal epithelial wound healing *in vitro* and *in vivo*. NanoImpact 17: 100198. https://doi.org/10.1016/j.impact.2019.100198.

Riden HE, Giacinto R, Wadsworth G, Rainwater J, Andrews T, Pinkerton KE. 2020. Wildfire Smoke Exposure: Awareness and Safety Responses in the Agricultural Workplace. *Journal of Agromedicine* 25(3): 330-338. https://doi.org/10.1080/1059924X.2020.1725699.

Patten KT, González EA, Valenzuela A, Berg E, Wallis C, Garbow JR, Silverman JL, Bein KJ, Wexler AS, Lein PJ. 2020. Effects of early life exposure to traffic-related air pollution on brain development in juvenile Sprague-Dawley rats. *Translational Psychiatry*, 10(1): 166. https://doi.org/10.1038/s41398-020-0845-3.

Berg EL, Pedersen LR, Pride MC, Petkova SP, Patten KT, Valenzuela AE, Wallis C, Bein KJ, Wexler AS, Lein PJ, Silverman JL. 2020. Developmental exposure to near roadway pollution produces behavioral phenotypes relevant to neurodevelopmental disorders in juvenile rats. *Translational Psychiatry*, 10(289): 1-16. https://doi.org/10.1038/s41398-020-00978-0.

Dahlem C, Kado SY, He F, Bein KJ, Kado N, Wu D, Haarmann-Stemmann T, Vogel CFA. 2020. AHR signaling interacting with nutritional factors regulating the expression of markers in vascular inflammation and atherogenesis. *International Journal of Molecular Sciences*, 21(21): 8287. https://doi.org/10.3390/ijms21218287.

Edwards S, Zhao G, Tran J, Patten KT, Valenzuela A, Wallis C, Bein KJ, Wexler AS, Lein PJ, Rao X. 2020. Pathological cardiopulmonary evaluation of rats chronically exposed to traffic-related air pollution. *Environmental Health Perspectives*, 128(12). https://doi.org/10.1289/EHP7045.

2019

Wu CW, Yau T, Fulgar CC, Mack SM, Revilla AM, Kenyon NJ, Pinkerton KE. 2019. Long-Term Sequelae of Smoking and Cessation in Spontaneously Hypertensive Rats. *Toxicol Pathol*. 48(3):422-436. https://doi.org/10.1177/0192623319893312,

Mack SM, Madl AK, Pinkerton KE. 2019. Respiratory Health Effects of Exposure to Ambient Particulate Matter and Bioaerosols. *Compr Physiol.* 10(1):1-20. https://doi.org/10.1002/cphy.c180040.

Pinkerton KE, Chen CY, Mack SM, Upadhyay P, Wu CW, Yuan W. 2019. Cardiopulmonary Health Effects of Airborne Particulate Matter: Correlating Animal Toxicology to Human Epidemiology. *Toxicol Pathol.* 47(8):954-961. https://doi.org/10.1177/0192623319879091.

Wei H, Zhang Y, Song S, Pinkerton KE, Geng H, Ro CU. 2019. Alveolar macrophage reaction to $PM_{2.5}$ of hazy day in vitro: Evaluation methods and mitochondrial screening to determine mechanisms of biological effect. *Ecotoxicol Environ Saf.* 174:566-573. https://doi.org/10.1016/j.ecoenv.2019.02.093.

Mack S, Shin J, Ahn Y, Castañeda AR, Peake J, Fulgar C, Zhang J, Cho Y, Pinkerton KE. 2019. Age-Dependent Pulmonary Reactivity to House Dust Mite Allergen: A Model of Adult-Onset Asthma? *Am J Physiol Lung Cell Mol Physiol.* 316(5). https://doi.org/10.1152/ajplung.00468.2018.

Kaur R, Labins JR, Helbock SS, Jiang W, Bein KJ, Zhang Q, Anastasio C. 2019. Photooxidants from brown carbon and other chromophores in illuminated particle extracts. *Atmospheric Physics and Chemistry*, 19: 6579-6594. https://doi.org/10.5194/acp-19-6579-2019.

2018

Wang Z, Wang L, Tapa S, Pinkerton KE, Chen CY, Ripplinger CM. Exposure to Secondhand Smoke and Arrhythmogenic Cardiac Alternans in a Mouse Model. *Environ Health Perspect.* 126(12):127001. https://doi.org/10.1289/EHP3664.

Smit-McBride Z, Nguyen J, Elliott GW, Wang Z, McBride RA, Nguyen AT, Oltjen SL, Yiu G, Thomasy SM, Pinkerton KE, Lee ES, Cunefare D, Farsiu S, Morse LS. 2018. Effects of aging and environmental tobacco smoke exposure on ocular and plasma circulatory microRNAs in the Rhesus macaque. *Mol Vis.* 24:633-646. https://pubmed.ncbi.nlm.nih.gov/30294202.

Albrengues J, Shields MA, Ng D, Park CG, Ambrico A, Poindexter ME, Upadhyay P, Uyeminami DL, Pommier A, Küttner V, Bružas E, Maiorino L, Bautista C, Carmona EM, Gimotty PA, Fearon DT, Chang K, Lyons SK, Pinkerton KE, Trotman LC, Goldberg MS, Yeh JT, Egeblad M. 2018. Neutrophil extracellular

traps produced during inflammation awaken dormant cancer cells in mice. *Science* 361(6409). https://doi.org/10.1126/science.aao4227.

Xu J, Qiu X, Liang Z, Smiley-Jewell S, Lu F, Yu M, Pinkerton KE, Zhao D, Shi B. 2018. Exposure to tobacco smoke increases bone loss in spontaneously hypertensive rats. *Inhal Toxicol.* 30(6):229-238. https://doi.org/10.1080/08958378.2018.1506838.

Castañeda AR, Vogel CFA, Bein KJ, Hughes HK, Smiley-Jewell S, Pinkerton KE. 2018. Ambient particulate matter enhances the pulmonary allergic immune response to house dust mite in a BALB/c mouse model by augmenting Th2- and Th17-immune responses. *Physiol Rep.* 6(18): e13827. https://doi.org/10.14814/phy2.13827.

Pinkerton KE, Poindexter ME. 2018. Harmful Interruptions: Impact of Smoking Patterns on Tumorigenesis and Emphysema. *Am J Respir Cell Mol Biol.* 59(2):133-134. doi: https://doi.org/10.1165/rcmb.2018-0151ED.

Zhang J, Fulgar CC, Mar T, Young DE, Zhang Q, Bein KJ, Cui L, Castañeda A, Vogel CFA, Sun X, Li W, Smiley-Jewell S, Zhang Z, Pinkerton KE. 2018. TH17-Induced Neutrophils Enhance the Pulmonary Allergic Response Following BALB/c Exposure to House Dust Mite Allergen and Fine Particulate Matter From California and China. *Toxicol Sci.* 164(2):627-643. https://doi.org/10.1093/toxsci/kfy127.

Castañeda AR, Pinkerton KE, Bein KJ, Magaña-Méndez A, Yang HT, Ashwood P, Vogel CFA. 2018. Ambient particulate matter activates the aryl hydrocarbon receptor in dendritic cells and enhances Th17 polarization. *Toxicol Lett.* 292:85-96. https://doi.org/10.1016/j.toxlet.2018.04.020.

Rice MB, Motto Malea N, Pinkerton KE, Schwartz J, Nadeau KC, Browner CM, Whitehouse S, Thurston GD. 2018. Realizing the Paris Climate Agreement to Improve Cardiopulmonary Health. Where Science Meets Policy. *Ann Am Thorac Soc.* 15(7):791-798. https://doi.org/10.1513/AnnalsATS.201803-203PS.

Hopkins LE, Laing EA, Peake JL, Uyeminami D, Mack SM, Li X, Smiley-Jewell S, Pinkerton KE. 2018. Repeated Iron-Soot Exposure and Nose-to-Brain Transport of Inhaled Ultrafine Particles. *Toxicol Pathol.* 46(1):75-84. https://doi.org/10.1177/019262331772.

2017

Sun X, Wei H, Young DE, Bein KJ, Smiley-Jewell SM, Zhang Q, Fulgar CCB, Castañeda AR, Pham AK, Li W, Pinkerton KE. 2017. Differential pulmonary effects of wintertime California and China particulate matter in healthy young mice. *Toxicol Lett.* 278:1-8. https://doi.org/10.1016/j.toxlet.2017.07.853.

Christensen S, Jaffar Z, Cole E, Porter V, Ferrini M, Postma B, Pinkerton KE, Yang M, Kim YJ, Montrose L, Roberts K, Holian A, Cho YH. 2017. Prenatal environmental tobacco smoke exposure increases allergic asthma risk with methylation changes in mice. *Environ Mol Mutagen.* 58(6):423-433. https://doi.org/10.1002/em.22097.

Castañeda AR, Bein KJ, Smiley-Jewell S, Pinkerton KE. 2017. Fine particulate matter ($PM_{2.5}$) enhances allergic sensitization in BALB/c mice. *J Toxicol Environ Health A.* 80(4):197-207. https://doi.org/10.1080/15287394.2016.1222920.

Zhao D, Qiu X, Wang B, Wang Z, Wang W, Ouyang J, Silva RM, Shi X, Kang K, Xu D, Li C, Zhong S, Zhang Y, Pinkerton KE. 2017. Epiphyseal Arterial Network and Inferior Retinacular Artery Seem Critical to Femoral

Head Perfusion in Adults with Femoral Neck Fractures. *Clin Orthop Relat Res.* 475(8):2011-2023. https://doi.org/10.1007/s11999-017-5318-5.

2016

Shen YH, Pham AK, Davis B, Smiley-Jewell S, Wang L, Kodavanti UP, Takeuchi M, Tancredi DJ, Pinkerton KE. 2016. Sex and strain-based inflammatory response to repeated tobacco smoke exposure in spontaneously hypertensive and Wistar Kyoto rats. *Inhal Toxicol.* 28(14):677-685. https://doi.org/10.1080/08958378.2016.1249812.

Barupal DK, Pinkerton KE, Hood C, Kind T, Fiehn O. 2016. Environmental Tobacco Smoke Alters Metabolic Systems in Adult Rats. *Chem Res Toxicol.* 29(11):1818-1827. https://doi.org/10.1021/acs.chemrestox.6b00187.

Antony VB, Redlich CA, Pinkerton KE, Balmes J, Harkema JR. 2016. National Institute of Environmental Health Sciences: 50 Years of Advancing Science and Improving Lung Health. *Am J Respir Crit Care Med.* 194(10):1190-1195. https://doi.org/10.1164/rccm.201608-1645PP.

Bayram H, Bauer AK, Abdalati W, Carlsten C, Pinkerton KE, Thurston GD, Balmes JR, Takaro TK. 2017. Environment, Global Climate Change, and Cardiopulmonary Health. *Am J Respir Crit Care Med.* 195(6):718-724. https://doi.org/10.1164/rccm.201604-0687PP.

Kuempel ED, Jaurand MC, Møller P, Morimoto Y, Kobayashi N, Pinkerton KE, Sargent LM, Vermeulen RC, Fubini B, Kane AB. 2016. Evaluating the mechanistic evidence and key data gaps in assessing the potential carcinogenicity of carbon nanotubes and nanofibers in humans. *Crit Rev Toxicol.* 47(1):1-58. https://doi.org/10.1080/10408444.2016.1206061.

Patchin ES, Anderson DS, Silva RM, Uyeminami DL, Scott GM, Guo T, Van Winkle LS, Pinkerton KE. 2016. Size-dependent deposition, translocation, and microglial activation of inhaled silver nanoparticles in the rodent nose and brain. *Environ Health Perspect.* 124(12):1870-1875. https://doi.org/10.1289/EHP234.

Castañeda AR, Pinkerton KE. 2016. Investigating the effects of particulate matter on house dust mite and ovalbumin allergic airway inflammation in mice. *Curr Protoc Toxicol.* 68:1-18. https://doi.org/10.1002/cptx.5.

Brown TA, Holian A, Pinkerton KE, Lee JW, Cho YH. 2016. Early life exposure to environmental tobacco smoke alters immune response to asbestos via a shift in inflammatory phenotype resulting in increased disease development. *Inhal Toxicol.* 28(8):349-56. https://doi.org/10.1080/08958378.2016.1175526.

Conferences and Presentations

2022

"Next Generation Wildfires: Firestorms at the Wildland-Urban Interface", KJ Bein, Keynote Address: NorCal Society of Environmental Toxicology and Chemistry 30th Annual Conference, Davis, CA, September 15, 2022.

"Emulating Near-Roadway Exposure to Traffic-Related Air Pollution via Real-Time Emissions from a Major Freeway Tunnel System", *KJ Bein, CD Wallis, JL Silverman, PJ Lein, and AS Wexler, International Particulate Toxicology Conference, Santa Fe, NM, August 28-31, 2022.

"Inflammatory and Atherogenic Biomarkers Associated with Exposure to Traffic- and Wildfire-Related PM", KJ Bein, T Young, S Kado, A Rossi, C Vogeley, T Haamann-Stemmann, M Denison, and *CFA Vogel., Society of Toxicology 61st Annual Conference, San Diego, CA, March 27-31, 2022.

2021

"Traffic-Related Air Pollution: A Risk Factor for Alzheimer's Disease", *KJ Bein and *PJ Lein, Invited Talk: EU Transport Derived Ultrafines and the Brain Effects (TUBE) Consortium, May 7, 2021.

"Emulating Chronic Near-Roadway Exposures for Studying Alzheimer's Disease", *KJ Bein, CD Wallis, KT Patten, AE Valenzuela, EL Berg, JL Silverman, AS Wexler, and PJ Lein, American Association for Aerosol Research 39th Annual Conference, virtual event, October 18-22, 2021.

"Emulating Near-Roadway Exposures for Health Effects Studies", KJ Bein, Keynote Address: Eighth Colombian Congress and International Conference on Air Quality and Public Health (CASAP VIII), Bogota, Colombia, November 3-5, 2021.

"Next Generation Wildfires: Firestorms at the Wildland-Urban Interface", KJ Bein., UC Davis-University of Sydney Wildfire Webinar Series, invited talk, July 20, 2021.

2020

"Analysis of molecular biomarkers indicating inflammation induced by wildfire and traffic related PM", S Kado, KJ Bein, T Young, M Denison, AS Wexler, N Kado, Y He, C Dahlem, and *CF Vogel, Environmental Health Sciences Center Annual Retreat, U.C. Davis, CA, Oct. 12-13, 2020.

"Differential Effects of Ultrafine, Fine, and Coarse PM from Imperial Valley, California", *SM Mack, E Laing, KJ Bein, and KE Pinkerton, Society of Toxicology 59th Annual Meeting, Anaheim, CA, March 15-19, 2020.

"Chronic Exposure to Real-Time Traffic Related Air Pollution Exacerbates and Accelerates Alzheimer's Disease Phenotypes in Wild-Type and TgF344-AD Rats", *KT Patten, AE Valenzuela, C Wallis, KJ Bein, AS Wexler and PJ Lein, Society of Toxicology 59th Annual Conference, Anaheim, CA, March 15-19, 2020.

"Wildfire Smoke and Health", *KJ Bein and *KE Pinkerton, UC Davis School of Veterinary Medicine, Science Sandwich Seminar Series, invited talk, December 14, 2020.

2019

"Near-Roadway Neurodevelopmental Disruption", EL Berg, KT Patten, AE Valenzuela, KJ Bein, *AS Wexler, PJ Lein, and JL Silverman, European Aerosol Conference - EAC 2019, Gothenburg, Sweden, August 25-30, 2019.

"Chronic Exposure to Real-time Traffic Related Air Pollution Increases Neuroinflammation and Exacerbates Plaque Burden in TgF344-AD Rats", KT Patten, AE Valenzuela, AY Taha, KJ Bein, *AS Wexler, and PJ Lein, European Aerosol Conference - EAC 2019, Gothenburg, Sweden, August 25-30, 2019.

"Next Generation Wildfires: Firestorms at the Urban-Wildland Interface", *KJ Bein, I Hertz-Picciotto, and AS Wexler, American Association for Aerosol Research 37th Annual Conference, Portland, OR, Oct. 14-18, 2019.

"Air Quality: An Interface Between Environment, Climate Change and Public Health", *SM Mack, KJ Bein, Q Zhang, CF Vogel, H Lugo, M Garcia and KE Pinkerton, Society of Toxicology 2019 Annual Conference, Baltimore, MD, March 10-14, 2019.

"Timing of Particulate Matter (PM) Exposure Alters the Atopic Response to House Dust Mite in a Mouse Model of Asthma", *SM Mack, KJ Bein, E Laing, L Hernandez and KE Pinkerton, American Thoracic Society 2019 International Conference, Dallas, TX, May 17-22, 2019.

"Organosulfates: A Missing Link between Air Pollution and Alzheimer's Disease", *PJ Lein, AS Wexler, KJ Bein, R Morgan, *EA Stone, HJ Lehmler, G LeFevre, I Al-Naiema, A Panwar, and S Mamillapalli., Human Toxicology and EHSRC Research Seminar, University of Iowa, May 3, 2019.

"Next Generation Wildfires: Firestorms at the Wildland-Urban Interface", *KJ Bein., Northern Arizona University, Institute for Tribal Environmental Professionals, invited talk, March 7, 2019.

2018

“Near-Roadway Exposure Studies: A Tale of Two Tunnels", KJ Bein, Oregon State University Department of Environmental and Molecular Toxicology Seminar Series, Corvallis, OR, invited talk, February 7th, 2018.

"Gestational and Early Postnatal Exposure to Traffic-Related Air Pollution Modulates Neuroinflammation and Increases Neurogenesis in Male and Female Rats", *K Patten, A Valenzuela, E Berg, JL Silverman, KJ Bein, AS Wexler, and PJ Lein, Society of Toxicology 57th Annual Meeting, San Antonio, TX, March 11-15, 2018.

"Protocol Development for Vehicle Emission Toxicity Testing for Particulate Matter", *KJ Bein, CF Vogel, and N Kado, California Air Resources Board, Sacramento, CA, March 29th, 2018.

"Differential Toxicity of PM from the Salton Sea Playa", KJ Bein, Environmental Health Sciences Center 3rd Annual Retreat, Davis, CA, April 2-4, 2018.

"Rapid Deployment Mobile Aerosol Sampling and Measurement Platform", *KJ Bein, CD Wallis, and AS Wexler, Environmental Health Sciences Center 3rd Annual Retreat, Davis, CA, April 2-4, 2018.

"Developmental Exposure to Traffic-Related Air Pollution Produces Behavioral Phenotypes Relevant to Neurodevelopmental Disorders", *EL Berg, KJ Bein, AE Valenzuela, K Patten, MC Pride, AS Wexler, PJ Lein, and JL Silverman, Environmental Health Sciences Center 3rd Annual Retreat, Davis, CA, April 2-4, 2018.

"Pilot Project Purview: Caldecott Tunnel and Salton Sea", KJ Bein, Environmental Health Sciences Center 3rd Annual Retreat, Davis, CA, April 2-4, 2018.

"Health Effects of Airborne Particulate Matter Near the Salton Sea: A Community-Based Exploratory Project in the Imperial Valley, CA", *SM Mack, KJ Bein, T Andrews, and KE Pinkerton, American Thoracic Society 2018 International Conference, San Diego, CA, May 20-26, 2018.

"Time Lag Histological Changes Following Acute Exposure to China and California Fine Particulate Matter (PM2.5)", *C Fulgar, XL Sun, W Li, HY Wei, DE Young, Q Zhang, XS Luo, LL Cui, KJ Bein, and K E Pinkerton, American Thoracic Society 2018 International Conference, San Diego, CA, May 20-26, 2018.

"Near-Roadway Effects on Expression of Autism Spectrum Disorder-Related Phenotypes", *KJ Bein, C Wallis, X Luo, EL Berg, MC Pride, K Patten, A Valenzuela, E Gonzalez, JL Silverman, PJ Lein, and AS Wexler, 10th International Aerosol Conference, St. Louis, MO, September 2-7, 2018.

"Near-Roadway Effects on the Progression of Alzheimer’s Disease", *KJ Bein, C Wallis, X Luo, K Patten, A Valenzuela, E Berg, JL Silverman, PJ Lein, and AS Wexler, 10th International Aerosol Conference, St. Louis, MO, September 2-7, 2018.

2017

"Comparison of Time Lag Effects of Wintertime California and China PM in Healthy Young Mice", *XL Sun, W Li, DE Young, HY Wei, LL Cui, KJ Bein, Q Zhang, JJ Zhang, A Magaña-Méndez, and KE Pinkerton, American Thoracic Society 2017 International Conference, Washington D.C., May 22-26, 2017.

"Differential California and China Fine Particulate Matter Effects on Allergic Sensitization to House Dust Mite in BALB/c Mice", *JJ Zhang, TC Mar, XL Sun, W Li, LL Cui, CC Fulgar, AR Castaneda, DE Young, Q Zhang, KJ Bein, ZZ Zhang, and KE Pinkerton, American Thoracic Society 2017 International Conference, Washington D.C., May 22-26, 2017.

"Facilitating Real-Time Exposure Studies on Traffic Related Air Pollution", KJ Bein, C Wallis, YJ Zhao, and *AS Wexler, American Association for Aerosol Research, Raleigh, NC, October 16-20, 2017.

"Facilitating Real-Time Exposure Studies on Traffic Related Air Pollution", KJ Bein, Environmental Health Sciences Center 2nd Annual Retreat, U.C. Davis, CA, December 1-2, 2017.

2016

"Investigating the Links Between Chemical Composition of Atmospheric Particulates and Adverse Health Effects", *DE Young, S Collier, X Sun, H Wei, KE Pinkerton, KJ Bein and Q Zhang, American Association for Aerosol Research, Portland, OR, Oct 17-21, 2016.

C.2. Website(s) or other Internet site(s) – include URL(s)

Center website: https://aghealth.ucdavis.edu/

C.3. Technologies or techniques

- Design, development, testing, and deployment of our Aerosol Sampling and Measurement Platform (ASAMP) for conditional sampling of air pollution coupled to real-time measurements of PM and gas phase concentrations and meteorological variables; see detailed description in Section B.2.
- Design, development, testing, and deployment of our Rapid Response Mobile Research Unit (2RMRU) for *in situ* wildfire sampling. PM and gas samplers, continuous emissions monitoring instrumentation, and a meteorological station have been integrated into an open 2-car hauler equipped with two electric vehicles that provide a clean and stable power supply. The car hauler is easily towed by a ¾ ton truck, enabling rapid deployment during wildfires and smoke events; see detailed description in section B.2.
- Design, characterization and implementation of novel extraction methods and cellular assays for chemical and toxicological characterization of collected PM samples.

C.4. Inventions, patent applications, and/or licenses
None

D. PARTICIPANTS

D.1. What individuals have worked on the project? Please include calendar, academic, and summer months.

Commons ID	S/K	Name	Degrees(s)	Role	Cal	Aca	Sum	Foreign	Country	SS
		Abarca, Radek		Student 3	0.45					
		Andrews, Teresa		Community Education Specialist 3	6.541					
		Arsage, Erica		Student 3	0.922					
		Bautista, Christine P		Student 3	0.19					
		Bein, Keith J		Associate Researcher	32.597					
		Carillo, David Seth J		Student 3	0.129					
		Castaneda, Alejandro R		Jr. Specialist	4.14					
		Clark, Taryn A		Student 3	2.748					
		Clark, Toby A		Jr. Specialist/Student 3	4.149					
		Cunha, Quinn P		Student 3	0.596					
		Echizenya, Shiori		Student 3	0.267					
		Edwards, Katherine A		Student 3	1.13					
		Espiritu, Imelda E		SRA 2	0.24					
		Fong, Katie		Student 3	0.05					
		Fox, Anna J		Student 3	1.564					
		Francisis, Hanna U		Student 3	0.498					

		Fulgar, Ciara C		Jr. Specialist	6.92					
		Giang, Colby		Student 3	0.24					
		Han, Ashley		Student 3	0.05					
		Hernandez , Lizeth		Student 3	0.38					
		Huynh, Huong		Student 3	2.293					
		Kaur, Harsimran		Student 3	0.5					
		Keil, Anna M		Student 3	0.129					
		Laing, Emilia A		Jr. Specialist,	0.491					
		Laing, Emilia A		Jr. Specialist	7.16					
		Laing, Emilia A		Student 3	3.11					
		Li, Xiaohan		GSR	1.846					
		Lin, Ryan		Student 3	0.2					
		Lopez, Cora H		Student 3	0.362					
		Mack, Savannah		GSR	0.105					
		Mar, Tiffany C.		Jr. Specialist	2.65					
		Miyashiro, Malia K		Student 3	0.395					
		Morrar, Deena		Student 3	0.379					
		Nguyen, Trami T		Student 3	0.52					
		Peake, Janice L		SRA 2	0.2					

		Perez-Rodriguez, Elissa		Student 3	0.35					
kepinkerton		Pinkerton, Kent E		PI, Professor HCOMP	1.35					
		Recio, Shannen Josh		Student 3	1.494					
		Revilla, Alina M		Student 3	0.61					
		Reyes, John Nathan S		Student 3	0.31					
		Ritter, Kerri M.		Student 3	1.345					
		Ryan, Hannah E.		Student 3	0.212					
		Silva, Rona M.		Writer Editor 3	0.356					
		Singh, Jasmine		Student 3	1.99					
		Singh, Neha		Student 3	0.908					
		Smiley Jewell, Suzette M.		Research Grant Program Officer 4	1.515					
		Stevenson, Delaney		Student 3	0.244					
		Taylor, Catherine A.		Student 3	0.71					
		Torres, Sheccid		Student 3	0.097					
		Uyeminami, Dale Lee		Staff Research Associate 3	11.528					
		Wu, Ching-Wen		Assistant Specialist	2.635					

		Yu, Jihau W.		Student 3	4.106					
		Zmich, Krysta L.		Jr. Specialist/Student 3	6.755					

D.2 Personnel updates

N.A.

E. IMPACT

E.1 - What is the impact on the development of human resources, if applicable?

N.A.

E.2 - What is the impact the Public Health Relevance and Impact? The investigator should address how the findings of the project relate beyond the immediate study to improved practices, prevention or intervention techniques, legislation, policy, or use of technology in public health.

The impact of air pollution in the area of agriculture has led to new training materials that have been produced to allow for individual and group training of workers in agriculture. These materials are unique in providing self-education approaches. These materials include easy-to-understand graphics and a simple dialogue for those providing new and/or repeated training of employees. An important feature of these training materials is the inclusion of a check-list for the farmer and the supervisor to ensure compliance and consistency in information provided to the farmworker, in particular for wildfire health implications to ensure worker safety and health. These materials are designed to allow viewers to understand air quality and wildfire issues independent of direct interaction with WCAHS.

F. CHANGES

F.1 – Changes in approach and reasons for change, including changes that have a significant impact on expenditures

One of the most understudied farming regions in California is the Salton Trough, which is composed of the Imperial and Coachella Valleys. This agricultural region is oftentimes called the “Winter Garden of California,” with extensive production in lettuce, alfalfa, and winter vegetables. It is also a region with the highest incidence of asthma in the state, which has been associated with poor air quality. Although our goals have not changed with ongoing research in the SJV and Central Valley, we have devoted significant attention to the Imperial Valley in response to strong recommendations from our Community Stakeholder Advisory Committee. With the help of high school students, we have collected size-segregated, temporally resolved, and wind direction-resolved PM samples using our mobile ASAMP deployed on the Calipatria High School campus in the Imperial Valley for subsequent chemical and toxicological characterization according to Specific Aim 2 and subsequent outreach activities via Specific Aim 3.

An emerging issue of concern for farmworker health and safety is co-exposure of farmworkers to agricultural-related emissions in combination with emissions from other sources that may be driven by climate change.

For California, the dominant concern by far is wildfires, and we have seen a major impact of wildfire emissions in agricultural areas over the last several wildfire seasons. Driven by climate change, wildfires are projected to increase in size, severity, and frequency, accompanied by an increase in the duration of the fire season and the geospatial extent of susceptibility. Farmworkers represent one of the most susceptible populations given they work throughout the fire season, spend extended hours outside performing physical labor, and tend to decline mitigation efforts. Furthermore, farmworkers are concentrated in the valleys of California where emissions tend to stagnate and build for sustained periods. As a result, we have extended the scope of our research goals to include the impact of wildfire emissions, in combination with agricultural emissions, on farmworker health and safety. These efforts included collecting PM samples from wildfires throughout Northern California and assessing composition and toxicity, alone and in combination with agricultural emissions, via Aim 2. Dissemination of these results and public outreach was done in accordance with Specific Aim 3.

F.2 - Actual or anticipated challenges or delays and actions or plans to resolve them
None

F.3 - Significant changes to human subjects, vertebrate animals, biohazards, and/or select agents
None

G. Special Reporting Requirements

G.1 Special Notice of Award Terms and Funding Opportunities Announcement Reporting Requirements
No special requests designated in the notice of award terms.

G.2 Responsible Conduct of Research
No special requests designated.

G.3 Mentor's Research Report or Sponsor Comments
No special requests designated.

G.4 Human Subjects

G.4.a Does the project involve human subjects?
No

G.4.b Inclusion Enrollment Data
N.A.

G.4.c ClinicalTrials.gov
N.A.

Does this project include one or more applicable clinical trials that must be registered in ClinicalTrials.gov under FDAAA?
No

G.5 Human Subject Education Requirement
Are there personnel on this project who are newly involved in the design or conduct of human subject's research?
No

G.6 Human Embryonic Stem Cells (HESCS)
Does this project involve human embryonic stem cells (only hESC lines listed as approved in the NIH Registry may be used in NIH funded research)?
No

G.7 Vertebrate Animals
Does this project involve vertebrate animals?
Yes

G.8 Project/Performance Sites
University of California, Davis

G.9 Foreign Component
None

G.10 Estimated Unobligated Balance
G.10.a Is it anticipated that an estimated unobligated balance (including prior year carryover) will be greater than 25% of the current year's total approved budget?
No

G.11 Program Income
Is program income anticipated during the next budget period?
No

G.12 F&A Costs
Is there a change in performance sites that will affect F&A costs?
No

I. OUTCOMES

I. Provide a concise summary of the outcomes or findings of the award, written for the general public in clear and comprehensible language, without including any proprietary, confidential information or trade secrets

Note: project outcome information will be made public in NIH RePORTER

Design, development, and deployment of our *(1)* Aerosol Sampling and Measurement Platform (ASAMP) for extensive air pollution, field sampling, and measurement campaigns throughout California's Sacramento, San Joaquin, and Imperial Valleys and *(2)* Rapid Response Mobile Research Unit (2RMRU) for *in situ* sampling of active wildfires throughout the 2017-2020 California fire seasons has resulted in an extensive and unmatched archive of PM samples available to us and other research groups for chemico-toxicological characterization as a function of particle size, source, composition, atmospheric processing, region, and environmental setting. A subset of these samples has already been thoroughly analyzed over the past six years through our WCAHS research efforts, numerous samples have been gifted to other research groups in the US and internationally for complementary and collaborative research projects, and there is still a vast reserve of samples archived for future research through both our WCAHS renewal and other internal and extramural funding mechanisms.

Through careful establishment of the most robust and scientifically sound methods for *(i)* extracting sampled PM from the collection substrates prior to toxicological testing, *(ii)* administering extracted PM for *in vitro* and

in vivo studies and *(iii)* providing a full chemical characterization of all PM samples used, we have successfully created a large and rich database on the chemical and toxicological properties of PM as a function of particle size, source, and atmospheric processing. Our studies have implemented cellular markers of inflammation and reactivity in novel cell culture systems, used animal models of healthy and allergic mice, and employed a comprehensive suite of analytical techniques to obtain these data. Results from all these efforts to understand the relative toxicity of different PM sources, including agriculture, wildfires, and vehicular emissions, have culminated in a large body of peer-reviewed publications, numerous presentations at scientific conferences, stakeholder organizations, expert panels, and symposia, as well as invited talks and several interviews through various media outlets. These outreach efforts have made our research highly visible and relevant to the public.

In collaboration with the WCAHS Outreach Core and several other institutions and stakeholder organizations, our research and peer-reviewed results have enabled the creation of a wide array of safety training materials and checklists, including videos and presentations as part of worker training in the field, wildfire safety and training materials, evaluation guidelines for COVID-19 safety and proper facemask use in agricultural settings, safety alerts on the spread of COVID-19 via respiratory droplets, and a survey-based brochure detailing how extreme weather events may impact the work, health, and safety of agricultural employers and farmworkers. These materials have been disseminated widely throughout California, including agricultural organizations, advocacy groups, labor contractors, state agencies, and farmworker communities, via several mechanisms like extensive mailing campaigns and in-person and virtual training efforts up and down the state. Adapting health promotion and workplace safety strategies to meet the multiple vulnerabilities and diverse needs of farmworkers is critical to successful implementation of workplace protection and safety measures. Also, these efforts have empowered farmworker communities and stakeholders with knowledge to advocate for change.

An extensive and impressive cohort of high school students, community members, advocacy organizational staff, undergraduates, graduate students, postdoctoral scholars, academic researchers, and visiting scholars have been involved in our studies over the past six years. These efforts and opportunities have provided training and professional development across various disciplines, career stages and trajectories, and public and private sectors. In total, our research efforts have had a positive impact on academia, industry, advocacy, state agencies, and farmworker communities through a confluence of heightened awareness of major issues impacting farmworker health and safety, potential mitigation, adaptation, and regulatory strategies, education and community outreach, strong interorganizational collaborative partnerships, and career development.

Western Center for Agricultural Health and Safety

Christopher W. Simmons, Ph.D.

Project 2: Reducing Toxin Exposure for Workers in Western Agriculture: Development of Sustainable Alternatives to Soil Fumigation

B. ACCOMPLISHMENTS

B.1. What are the major goals of the project?

Soil fumigants are used to eliminate pests in the soil that can cause significant damage to crops. However, conventional soil fumigants have been identified by federal and state regulatory agencies as carcinogens and both acute and cumulative toxins. Several incidences of disease stemming from accidental fumigant exposure, involving both agricultural workers and nearby residents in agricultural communities, highlight the need to reduce exposure risk. This project addresses the need to reduce exposure risk of agricultural workers and nearby farm communities associated with toxic soil fumigants; it is relevant to NIOSH/CDC's mission to improve worker health and safety in agriculture by developing evidence-based solutions. Currently, less toxic fumigant alternatives are less effective than fumigants or their efficacy is variable, which prevents widespread adoption. Progress in the field of soil disinfestation without toxic fumigants is blocked by a lack of deployable and well-characterized substitute practices that are versatile, effective, and straightforward. Our long-term goal is to reduce the use of soil fumigants that are hazardous to human health and minimize fumigant exposure risk for agricultural workers and the general population living near fumigated fields. The overall objective of this research is to validate a novel soil pest inactivation technology, biosolarization, as a safe and effective fumigation alternative.

Biosolarization is a new technique that combines soil biofumigation and soil solarization. It is our central hypothesis that biosolarization is effective in controlling major agricultural pests and can substitute for or be used in combination with minimal soil fumigation for pest management. We further hypothesize that adoption of biosolarization will eliminate exposure risks associated with many soil fumigants. Our preliminary data have shown biosolarization results in temporary volatile fatty acid (VFA) accumulation in the soil. These VFAs can inactivate pests but are far less toxic than many conventional fumigants (the NIOSH exposure limit for the popular fumigant chloropicrin is 50-100x lower than the limits for the VFAs produced during biosolarization). This hypothesis is also supported by our previously published biosolarization research and the work of others (Butler et al., 2012; Simmons et al., 2013; Achmon et al., 2015). The rationale of the proposed research is that biosolarization must be validated under conditions that would be encountered in commercial agriculture. This research will test biosolarization efficacy, safety, and fumigant displacement potential under practical conditions.

We propose the following aims to test our hypotheses:
Aim 1: Establish that biosolarization can effectively utilize abundant fruit processing residues to inactivate agricultural weeds and nematodes. We will use laboratory studies to determine optimal conditions for pest inactivation and field trials to compare pest inactivation in soils treated with fumigation, biosolarization, and biosolarization paired with minimal fumigation.

Aim 2: Assess biosolarization efficacy for pest control and compatibility with crops when used alone or in conjunction with minimal fumigation. Biosolarization with and without soil fumigation will be compared in field studies by measuring the performance of major western crops in treated soils. Any unique benefits to crops from increasing soil organic matter via biosolarization will also be examined.

Aim 3: Assess the exposure risk reduction associated with the use of biosolarization alone and with minimal fumigation. Safety and efficacy implications of biosolarization relative to conventional fumigation will be

determined based on the NIOSH exposure limits of fumigants, compounds produced during biosolarization, and empirical emissions and pest inactivation data from previous Aims.

Aim 4: Develop outreach materials in collaboration with the Outreach Core for growers and stakeholders in commercial agriculture. Outreach materials will communicate biosolarization best practices and deliver information to promote adoption of soil fumigation alternatives.

The expected outcome of this research is to determine the safety and health benefits of biosolarization as a fumigant alternative. From this we will provide actionable data for growers to adopt biosolarization in lieu of soil fumigation with toxic compounds.

B.2. What did you accomplish under these goals?

During the reporting period, several major activities related to the project objectives were conducted. These activities yielded data and findings that advance the stated goals of the project. Specifically, the following activities were accomplished during the reporting period:

1. Measurement of long-term control of phytoparasitic nematodes in biosolarized soils.
2. Reporting of volatile organic compounds produced in biosolarized soils including compounds relevant to pest control and agricultural worker safety.
3. Elucidation of persistent biosolarization benefits that can incentivize adoption of biosolarization as a replacement for conventional toxic fumigants.
4. Extension of biosolarization research into new California food industries to enable wider adoption.
5. Continued outreach and engagement of the California almond industry to promote pesticide alternatives.

Within the above activities, key findings include confirmation of long-term control of root lesion and root knot nematodes at a biosolarization field site. The site was biosolarized 3 years ago and continues to suppress these phytoparasites. In contrast, the control plots have seen reinfestations. These data are important for convincing growers that biosolarization can deliver long-term pest control efficacy and be a substitute for fumigation.

We have also published a study regarding volatile organic compound (VOC) evolution in soils biosolarized with almond hull and shell amendments. Fifty-one VOCs were detected in biosolarized soil spanning alcohols, aldehydes, aromatic compounds, esters, organic acids, sulfides, ketones, and terpenes. Aqueous concentrations of each VOC measured in the soil were used to calculate the corresponding partial pressures in the soil air space and tarp head space. These estimates, which represent the maximum concentrations that a worker would possibly encounter in a biosolarized field, were compared against NIOSH exposure limits. All compounds measured were at least two orders of magnitude below their exposure limits, indicating very minimal risk to workers. These results quantitatively demonstrated the worker health and safety benefits of biosolarization compared to conventional toxic fumigants. Having now been peer-reviewed and published, these data strengthen the ability for growers and policymakers to classify biosolarization as a safer alternative to soil fumigation.

In order to increase the likelihood of growers adopting biosolarization over fumigation, we have elucidated other benefits associated with biosolarization that cannot be achieved through conventional fumigation alone. Specifically, we have demonstrated that multi-year elevations in soil nitrogen, potassium, and carbon are possible via biosolarization. These changes can improve soil fertility and water retention, benefitting crops.

In a continued effort to make biosolarization as versatile and broadly applicable as possible, we have studied additional biosolarization soil amendments that are available at low cost and may have unique pest-inactivating properties. For instance, we have started to assess industrial onion processing residues (the cuttings from the ends and outer layers of the onion) for use in biosolarization. The sugars and endogenous biopesticides in these residues may infuse the soil with pest-inactivating compounds while promoting fermentative production of additional biopesticides during biosolarization. Currently, laboratory studies are being conducted under simulated biosolarization conditions to gauge pest inactivation and crop compatibility phenomena.

Finally, we have advanced our outreach goals to promote biosolarization by continuing to engage the California almond industry. We have received complementary funding from the Almond Board of California to continue monitoring a biosolarized orchard site in order to highlight the longer-term benefits of biosolarization on soil and tree health that may help to promote adoption among growers. The Almond Board of California has also published an article and interview with Prof. Simmons about biosolarization in their magazine, “How We Grow,” which is circulated widely among almond growers:

“Almond Hulls, Shells Help Fuel an Alternative to Fumigation.” How We Grow; Nov/Dec 2020 issue 12. Almond Board of California.

During the extension period, additional research was completed to extend assessment of the biosolarization field trial site in Chico, CA as well as to expand understanding of biosolarization efficacy in the context of onion production. Specifically, analysis of soil samples from the almond orchard field site showed that there were no detectable differences in soil nematode populations (for both phytoparasites and the overall nematode food web) among biosolarized soils and untreated controls in May 2022. This contrasts with earlier data that demonstrated significant reductions in harmful nematodes in the biosolarized soils compared to the control soils. These results indicated that, much like conventional soil fumigation, there is an upper limit for the duration of soil pest control. The data show that the duration of control for biosolarization is comparable to published values for soil fumigation.

For biosolarization in onion production, recent experiments have explored biosolarization using onion processing residues (peels and cuttings) as soil amendments. The experiments have defined the appropriate amendment types (red and white onion residues) and the interaction effects between amendment type, soil temperature, and treatment duration on the production of biopesticides in the soil and inactivation of nematode parasites. Additionally, biopesticide production and retention in different soil textures was measured.

B.3. Competitive Revisions/Administrative Supplements

Year 6 – additional year of funding through NIOSH. See B2 for accomplishments associated with Year 6 activities.

B.4. What opportunities for training and professional development did the project provide?

The project has supported the professional development of one Ph.D. student and an Assistant Researcher. For the graduate student, the project has afforded opportunities to become more familiar with agricultural health and safety issues surrounding pesticide use in California. Additionally, it has allowed for training in scientific writing (by way of preparing multiple manuscripts that have either been published or submitted) and experimental design and analysis. The project has also allowed the student to develop professional skills for

interfacing with industry stakeholders via collaborative field trials with commercial growers and presentations at industry events.

The Assistant Researcher, a former postdoctoral scholar in his second year within the professional staff researcher series at UC Davis, was involved in development activities to position him towards an eventual faculty position. This included having more direct oversight over certain field trial experiments and more opportunities to interact directly with industry collaborators.

B.5. How did you disseminate the results to communities of interest?

A publication in a peer-reviewed scientific journal was used to disseminate information on the volatile compounds generated during biosolarization. The article represents the first published report of an untargeted profiling of biosolarization volatile organic compounds, capturing compounds relevant to pest inactivation, crop interaction, odors, environmental health, and human health and safety. Notably, this paper reports data that assist in quantifying the decrease in worker exposure risk for biosolarization compared to conventional fumigants. The audience for this article is researchers and policymakers seeking to advance fumigant alternative pest management practices.

Presentations and demonstrations have also been used to communicate project findings to other researchers. Prof. Simmons was an invited speaker at the 2020 virtual meeting and expo of the American Chemical Society. Roughly 4,200 attendees registered for this event.

Media Interviews
Interviewed for article "Almond Hulls, Shells Help Fuel an Alternative to Fumigation", Magazine Article, 2020, Almond Board of California - How We Grow - Nov/Dec 2020, Issue 12. (no link available)

Interviewed for California Ag Today segment, Radio Interview, 2020, Ag Information Network of the West. https://www.aginfo.net/report/47618/California-Ag-Today/Biosolarization-Part-1

Interviewed for article "Hull and Shell Residues in the Almond Industry Could be Used to Help the Orchard", Website, 2020, Ag Information Network of the West. https://www.aginfo.net/report/45237/California-Tree-Nut-Report/Hull-and-Shell-Residues-in-the-Almond-Industry-Could-be-Used-to-Help-the-Orchard

Interviewed for article "Using the power of the sun is organic way to fumigate", Website, 2020, AgAlert. https://www.agalert.com/story/?id=13964

Research profiled in "Biosolarization a Potential Tool for Producers?", Website, 2019, AgNet West. http://agnetwest.com/biosolarization-potential-tool-producers/

B.6 - What do you plan to do during the next reporting period to accomplish the goals?

Not applicable. The six-year period of this grant is complete.

C. PRODUCTS

C.1. Publications, conference papers, and presentations

Publications

2022
Haber, Z., Wilhelmi, M.D.M.R., Fernández-Bayo, J.D., Harrold, D.R., Stapleton, J.J., Toubiana, D., VanderGheynst, J.S., Blumwald, E., Simmons, C.W., Sade, N. and Achmon, Y., 2022. The effect of circular

soil biosolarization treatment on the physiology, metabolomics, and microbiome of tomato plants under certain abiotic stresses. Frontiers in Plant Science, *13*.

Simmons, C.W., Shea, E.A., Lone, T., Hodson, A., Crowley, R., and Stapleton, J.J. 2022. Biosolarization: Returning Almond Hulls and Shells to the Orchard to Improve Soil and Almond Tree Health. Progressive Crop Consultant, 7(3), pp. 20-25.

2021
Shea, E.A., Wang, Z., Allison, B., and Simmons, C.W. 2021. Alleviating Phytotoxicity of Soils Biosolarized with Almond Processing Residues. Environmental Technology and Innovation, 23, 101662.

Shea, E.A., Fernandez-Bayo, J.D., Hodson, A.K., Parr, A.E., Lopez, E., Achmon, Y., Toniato, J., Milkereit, J., Crowley, R., Stapleton, J.J., VanderGheynst, J., and Simmons, C.W. 2021. Biosolarization Restructures Soil Bacterial Communities and Decreases Parasitic Nematode Populations. Applied Soil Ecology, 172, 104343.

Pastrana, A.M., Shea, E.A., Fernandez-Bayo, J.D., Allison, B., Watson, D.C., Toniato, J., Gordon, T.R. and Simmons, C.W., 2021. Impact of biosolarization with almond hull and shell amendments for the control of *Fusarium oxysporum* f. sp. lactucae in a lettuce/tomato cropping system. Crop Protection, 105856.

2020
Fernandez-Bayo, J.D., Shea, E.A., Parr, A.E., Achmon, Y., Stapleton, J.J., VanderGheynst, J.S., Hodson, A.K. and Simmons, C.W., 2020. Almond processing residues as a source of organic acid biopesticides during biosolarization. Waste Management, 101, pp.74-82.

Shea, E., Fernandez-Bayo, J.D., Pastrana Leon, A.M. and Simmons, C., 2020. Identification and Evaluation of Volatile Organic Compounds Evolved During Solarization with Almond Hull and Shell Amendments. Journal of the Air & Waste Management Association, 71.3, pp. 400-412.

2019
Shea, E., and Simmons, C.W., 2019. New Outlooks for Hull and Shell Management Options Using Biosolarization. West Coast Nut.

Theses and Dissertations

2020
Shea, Emily. 2020. Soil Biogenic Pesticide Formation and Transportation During Biosolarization Using Almond Processing Waste Amendments. University of California, Davis, ProQuest Dissertations Publishing.

2018
Lopez, Emily. 2018. Temporal Changes in Soil Phytonutrient Levels Following Biosolarization with Almond Waste Amendments and Associated Effects on Almond Tree Performance. University of California, Davis, ProQuest Dissertations Publishing.

Parr, Amy. 2018. The Sensitivity of *Pratylenchus vulnus* to Biosolarization. University of California, Davis, ProQuest Dissertations Publishing.

Conferences and Presentations (with published abstracts)

2020
2020, Simmons, C.W. Utilization of almond processing residual biomass for soil biosolarization. ACS Fall 2020 VIRTUAL Meeting & Expo.

2019

2019, E.A Shea, E. Lopez, J.D. Fernandez Bayo, J. Milkereit, Y. Achmon, R. Crowley, A.K. Hodson, J.J. Stapleton, J.S. VanderGheynst, C.W. Simmons. Preplant Orchard Biosolarization with Almond Residue Amendments Decreases Lesion and Ring Nematodes in Soil. MBAO: Fumigation and Alternatives for Production, Storage and Trade Conference, November 11-12, 2019; San Diego, CA.

2018
2018, E.A. Shea, E. Lopez, J.D. Fernandez Bayo, A.E. Parr, J. Milkereit, Y. Achmon, A.K. Hodson, J. Stapleton, J.S. VanderGheynst, C.W. Simmons. Using biosolarization with almond byproduct amendments to disinfest almond orchard soil during preplant processing and improve soil quality. 2018 American Chemical Society National Meeting, August 19-23, 2018; Boston, MA.

2018, E.A Shea, E. Lopez, J.D. Fernandez Bayo, J. Milkereit, Y. Achmon, R. Crowley, A.K. Hodson, J.J. Stapleton, J.S. VanderGheynst, C.W. Simmons. Using biosolarization with almond processing residue amendments to disinfest orchard soil. MBAO: Fumigation and Alternatives for Production, Storage and Trade Conference, 13-14 November, 2018; Orlando, Florida.

2017
2017, Fernández-Bayo, J.D., A.E. Parr, Y. Achmon, E.A. Shea, E. A. Lopez, J.J. Stapleton, J.S. VanderGheynst, A.K. Hodson, C.W. Simmons. Nematicidal Activity of Biosolarization Using Almond Waste Amendments. 2017 Methyl Bromide Alternatives Outreach Conference, November 13-15, 2017; San Diego, CA.

Presentations (no abstracts)

2021
May 26, 2021, Utilization of almond processing residual biomass for soil biosolarization, Invited Presenter, USDA Food Loss and Waste Innovation Virtual Fair - Almond Board booth, Virtual conference.

2020
August 20, 2020, Utilization of almond processing residual biomass for soil biosolarization, Invited Speaker, ACS Fall 2020 Virtual Meeting & Expo, Virtual Conference.

2019
September 19, 2019, Recycling solid organic residues from California food processing as soil amendments, Invited speaker, UC Davis Postharvest Center Workshop: Fresh cut products: Maintaining quality and safety, Davis, CA.

November 20, 2019, Biosolarization as a sustainable integrated pest management strategy, Invited speaker, Department of Biological and Agricultural Engineering Seminar Series, UC Davis.

December 11, 2019, Alternatives for Managing Replant Pests and Problematic Weeds, Invited speaker, The Almond Conference, Sacramento, CA.

2018
March 8, 2018, Development of Natural Amendments from Food Processing Residues to Improve Soil Health, Invited speaker, Natural Products Expo West, Anaheim, CA.

April 26, 2018, Bioconversion of tomato processing waste to value-added coproducts, Invited speaker, Food Waste in Food Systems course, Cal Poly, San Luis Obispo, CA.

November 16, 2018, Recycling solid organic residues from California food processing as soil amendments for biosolarization residues from California food processing as soil amendments for biosolarization, Invited speaker, CA Bioresource Alliance Symposium. Sacramento, CA.

December 13, 2018, Recycling Tomato Pomace as Soil Amendments for Biosolarization, Invited speaker, California Processing Tomato Symposium, Davis, CA.

2017
June 5, 2017, Biosolarization - A sustainable integrated pest management approach and pesticide alternative, Presenter, Weed Science seminar series, UC Davis.

December 5, 2017, Almond Biomass: The Real, Weird and Wonderful Opportunities for Greater Utilization, Invited speaker, The Almond Conference, Sacramento, CA

2016
December 5, 2016, Solarization and biosolarization as sustainable fumigation alternatives for california agriculture, Presenter, Western Center for Agricultural Health and Safety seminar series, Davis, CA.

C.2. Website(s) or other Internet site(s) – include URL(s)

Center website: https://aghealth.ucdavis.edu/
Facebook: https://www.facebook.com/AgHealthUCD
Twitter: https://twitter.com/AgHealthUCD
Instagram: https://www.instagram.com/aghealthucd/
YouTube: https://www.youtube.com/channel/UCCrF9GcijzIdd2shYwCFGjw

C.3. Technologies or techniques
None

C.4. Inventions, patent applications, and/or licenses
None

C.5. Other products and resource sharing
None

D. PARTICIPANTS

D.1. What individuals have worked on the project? Please include calendar, academic, and summer months.

Commons ID	S/K	Name	Degrees(s)	Role	Cal	Aca	Sum	Foreign	Country	SS
		Achmon, Ygal		Postdoc	8					
		Allison, Brittany J		Postdoc	13					
		Andrews, Teresa		Community Education Specialist 3	5.39					
		Bennett, Deobrah H		Professor			1.25			

		Chen, Stephanie S.		GSR		0.48				
		Fernandez Bayo, Jesus Dionisio		Assistant Researcher	5.99					
		Greenwood, Brittany B		GSR		0.93				
		Lone, Tate Channing		GSR		2.34				
		Milkereit, Janina		Postdoc	0.37					
		Pastrana Leon, Ana Maria		Postdoc	3					
		Shea, Emily		GSR		17.79				
		Shea, Emily		Postdoc	2.94					
		Simmons, Christopher W		Associate Researcher			0.85			
		Simmons, Christopher W		Researcher			0.66			
		Toniato, Juliano		GSR		2.11				

D.2 Personnel updates
N.A.

E. IMPACT

E.1 - What is the impact on the development of human resources, if applicable?
N.A.

E.2 - What is the impact the Public Health Relevance and Impact? The investigator should address how the findings of the project relate beyond the immediate study to improved practices, prevention or intervention techniques, legislation, policy, or use of technology in public health.

The products of the research have enabled grower adoption of biosolarization as an alternative to toxic soil fumigation. Within the project, the field trials have displaced fumigation at two commercial fields. The results of the field and laboratory studies provide actionable data for other growers in the western region to assess and translate biosolarization in their operations. The research has highlighted the soil health, crop health, sustainability, and human health benefits of biosolarization in the context of conventional agriculture to

incentivize the adoption of biosolarization to replace soil fumigation. By extension, the research promotes mitigation of worker and community exposure to toxic pesticides.

F. CHANGES

F.1 - Changes in approach and reasons for change, including changes that have a significant impact on expenditures

There has been a shift in the outreach approach. Originally, we planned to develop a survey and disseminate it to farm owners to gauge awareness of biosolarization and perceptions that could affect adoption. However, we have had success with more targeted engagement of agricultural commodity groups and growers via industry presentations, field days, and collaborative field trials on commercial farms. In this way, we have learned about the questions that growers have regarding the technology through direct interaction in lieu of the survey. The direct interactions have had the added benefit of permitting dialogue to clarify grower opinions and assess various ways to answer grower questions.

F.2 - Actual or anticipated challenges or delays and actions or plans to resolve them

Not applicable

F.3 - Significant changes to human subjects, vertebrate animals, biohazards, and/or select agents
Not applicable

G. Special Reporting Requirements

G.1 Special Notice of Award Terms and Funding Opportunities Announcement Reporting Requirements
N.A.

G.2 Responsible Conduct of Research
N.A.

G.3 Mentor's Research Report or Sponsor Comments
N.A.

G.4 Human Subjects
G.4.a Does the project involve human subjects?
No

G.4.b Inclusion Enrollment Data
N.A.

G.4.c ClinicalTrials.gov
N.A.

Does this project include one or more applicable clinical trials that must be registered in ClinicalTrials.gov under FDAAA?
No

G.5 Human Subject Education Requirement
Are there personnel on this project who are newly involved in the design or conduct of human subject's research?

No

G.6 Human Embryonic Stem Cells (HESCS)
Does this project involve human embryonic stem cells (only hESC lines listed as approved in the NIH Registry may be used in NIH funded research)?
No

G.7 Vertebrate Animals
Does this project involve vertebrate animals?
No

G.8 Project/Performance Sites
University of California, Davis

G.9 Foreign Component
No

G.10 Estimated Unobligated Balance
N.A.

G.10.a Is it anticipated that an estimated unobligated balance (including prior year carryover) will be greater than 25% of the current year's total approved budget?
No

G.11 Program Income
Is program income anticipated during the next budget period?
No

G.12 F&A Costs
Is there a change in performance sites that will affect F&A costs?
No

I. OUTCOMES

I. Provide a concise summary of the outcomes or findings of the award, written for the general public in clear and comprehensible language, without including any proprietary, confidential information or trade secrets

Note: project outcome information will be made public in NIH RePORTER

Experiments were conducted to examine biosolarization in California agriculture and address barriers to adoption for biosolarization as an alternative to conventional soil fumigation with toxic chemicals. This entailed using major sources of residual biomass in the state, such as hulls and shells from almond processing, as soil amendments to trigger production of natural biopesticides and other pest-inactivating conditions during biosolarization. Following field trials in 2017 that demonstrated control of soil pests immediately following biosolarization, ongoing monitoring of field sites has shown long-term benefits to soil health associated with biosolarization, including persistent pest suppression and elevated plant nutrient content. Specifically, biosolarization guarded against reinfestation by harmful nematodes for approximately two years, while promoting increased levels of plant nutrients in treated soils; by four years post-treatment, soil pest and nutrient properties in biosolarized and untreated soils became more similar. However, ongoing monitoring of soil and almond tree properties at the trial site have shown that certain varieties of almond trees in biosolarized soils exhibit greater trunk diameters and greener canopies than those grown in

untreated soils. These are indicators of increased vigor that may lead to improved yield. Industry engagement continues to be an integral element of this project. To further expand the applicability of biosolarization in western agriculture, new regional sources of compatible organic matter soil amendments continue to be explored. Residues from commercial onion processing have proven to be effective in laboratory pest control studies by yielding high levels of biopesticides and phytoparasite control during biosolarization. Across all aspects of the project, direct collaboration with commercial growers and food processors, presentations at industry events, and publication of articles in agricultural trade journals were used to increase grower awareness and promote adoption of biosolarization.

Western Center for Agricultural Health and Safety

Fadi Fathallah, Ph.D.

Project 3: Ergonomic and Biomechanical Evaluation of Mechanical and Robotic Strawberry Harvest-Aids

B. ACCOMPLISHMENTS

B.1. What are the major goals of the project?

Using a series of optimized and controlled interventions, we will gain a better understanding of the balance between the productivity and ergonomics of multi-person and personal labor-aid machines for strawberry harvesting and will evaluate machine-specific interventions for their safe deployment.

The specific aims for this project are to: 1) investigate the combined effects of operating speed and time breaks for multi-person machines on productivity, biomechanical response, fatigue, and symptoms of musculoskeletal disorders (MSD); 2) develop software for robot operation to maximize productivity and biomechanical response, while minimizing fatigue and MSD symptoms; and 3) develop guidelines for the speed settings of large harvest-aid machines and rest breaks for their crews, and algorithms that implement ergonomically sound operation for single-person programmable machines.

B.2. What did you accomplish under these goals?

Harvest Aids Simulation and Evaluation

One of the project objectives was to replicate the harvest aid but aimed for indoor and outdoor settings. The design criteria were driven by biomechanical relevance, material cost, lead time, and setup time. We began our design by drawing inspiration from the Berry Ferry by GK Machine Inc. (Donald, OR). This route would ensure semblance between equipment and replica because GK was the original equipment manufacturer for a site visit (Salinas, CA). A commercial strawberry farm was visited to gather insights into the Berry Ferry and its operations (Figure 1). During the site visit, photogrammetry of the Berry Ferry was taken and served as the source for dimensions. At the same time, video footage informed us of real-world operations and logistics. Lastly, verbal feedback from the strawberry workers was collected.

Figure 1. Field visit to one grower who uses the multi-person strawberry harvest aid in Salinas, CA.

Based on biomechanics principles, we concluded that docking height was the most critical dimension. This dimension dictates the degree of forward flexion during the drop-off phase of harvest. Biomechanically, forward flexion alters the loads on the spinal tissue. Research from Wilke and colleagues (1999) found that standing produces 0.50 MPa, while upright stooping can produce 1.10 MPa. Thus, ensuring docking height was critical to the generalizability of our lab-based results. Table 1 summarizes the design objectives for the “Traveling Platform.”

Table 1. *Harvest Aid Replica design objective*

Objective	Measurement
Accommodate 4 workers	12-foot-wide docking platform
Depth of Shelf	12 inches
Docking Height	38 inches
Turning Radius	11-foot-wide dirt road
Wheel width	12-inch furrow
Bed Furrow Clearance	28 inches

Several prototypes simulating the harvest aids were considered. A prototype was built, which had the characteristics of the field harvest aids (Figure 2).

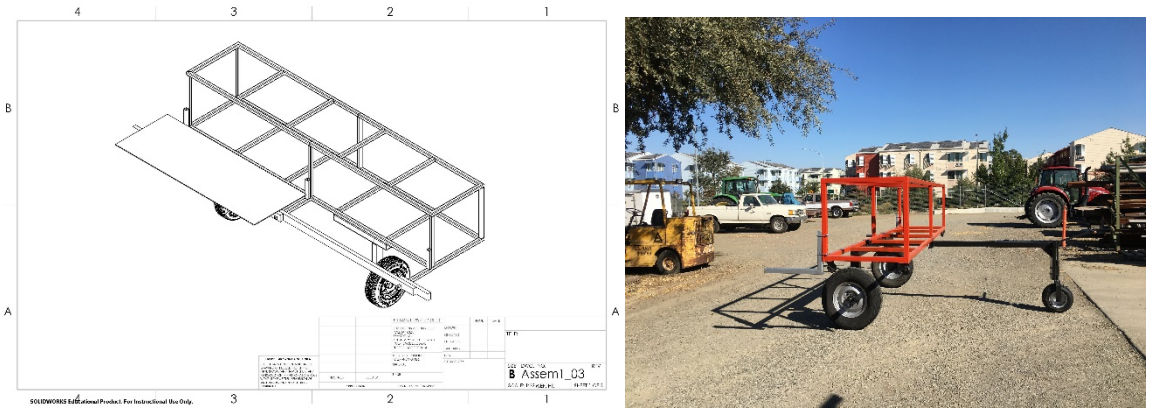


Figure 2. Custom-built multi-person harvest aid to allow simulating various harvesting scenarios.

Figure 3 showcases the prototype used in the study. The large pneumatic tires and simple frame allow for real-world and laboratory use. The prototype can accommodate up to three workers. Moreover, all biomechanically relevant dimensions matched the Berry Ferry. One missing feature from the replica is onboard propulsion. Nevertheless, a single operator can set up and move the Traveling Platform within the three-minute transfer window.

(A)

(B)


(C)

(D)

Figure 3. Replica views: (A) replica U-bolt fasteners, (B) replica isometric view, (C) front view, (D) side view.

Strawberry bed furrows

Furrows are parallel trenches made for carrying water. Strawberries are grown on the ridges with furrows between the beds. To create these forms, tillage equipment plows and moves soil to one side, creating the shape. In commercial settings, bed furrows differ from smaller operations. Mainly, furrow ridges are taller in commercial settings. We aimed to replicate the commercial setting in line with field characteristics. However, access to commercial tillage equipment was limited. This constraint led to the decision to simulate the bed furrows using wooden structures. Thus, the research aim was revised to simulate commercial strawberry harvest in controlled settings.

Mock Bed Furrows

The mock beds' references were derived from the previously mentioned site visit (Salinas, CA). Photogrammetry also taken that day served to extract dimensions such as bed top width, bed height, and furrow width (Figure 4). Verbal feedback from workers helped us understand the nuances of picking time and picking advancement. In addition, we consulted with the strawberry harvest expert Bruce Campopiano (UC Davis). Mr. Campopiano advised us on the proper equipment needed to replicate strawberry fields. Lastly, time studies from previously published work (Peng &Vougioukas, 2020) were also referenced.

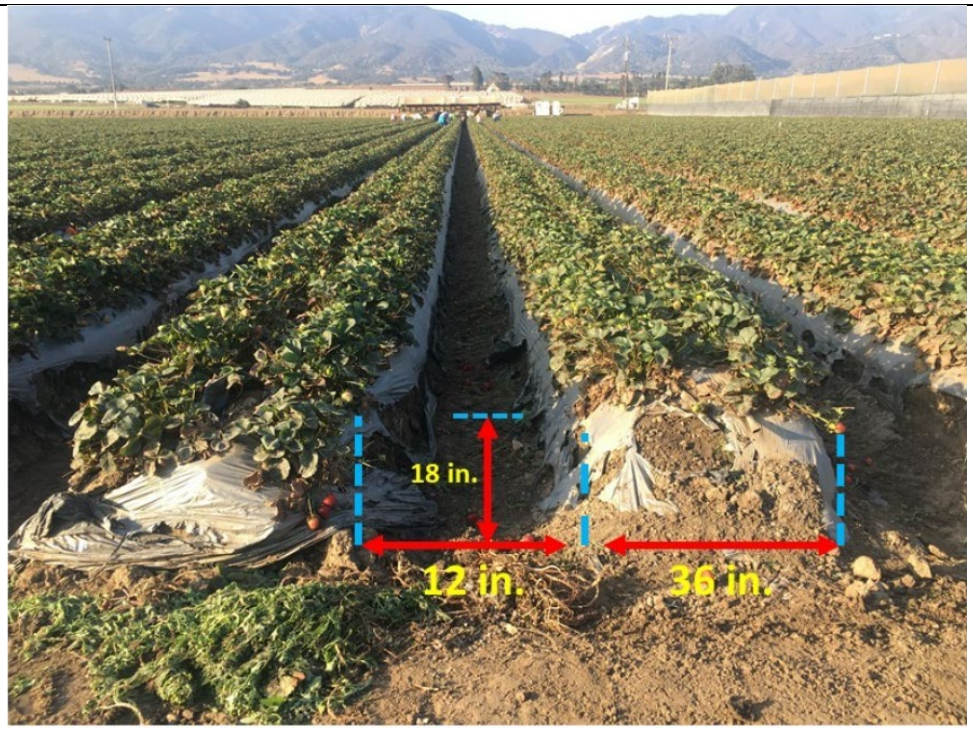
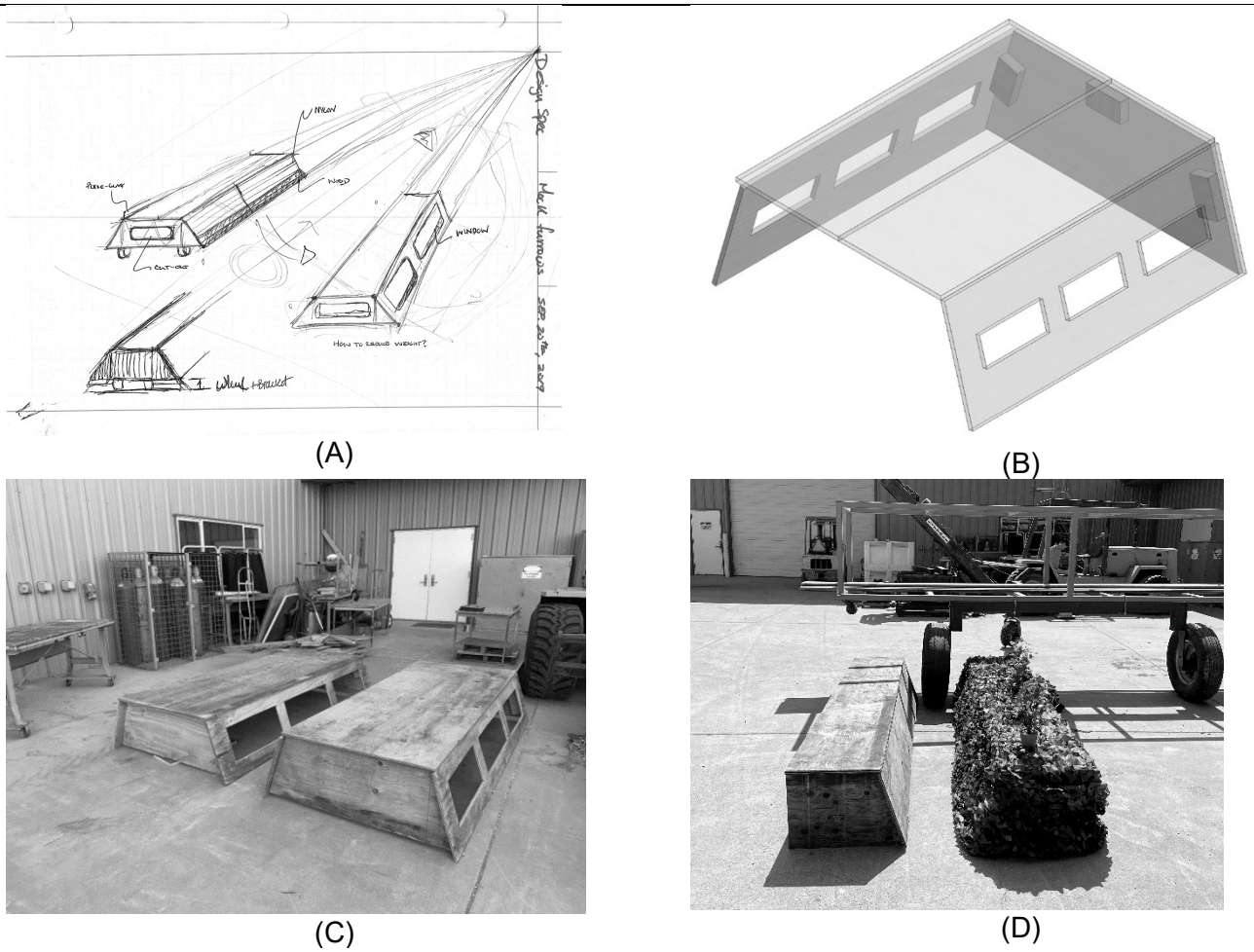


Figure 4. Strawberry bed furrows (Salinas, CA).

Once the overall dimensions were established, the design identified the biomechanically relevant dimensions. Previously, we explained the relationship between forward flexion, docking height, and biomechanics. Similarly, the biomechanics principles governing the docking height extend to bed height. Another relevant dimension was bed width. This dimension can also influence the load on the spine because wider beds can place workers into over-extended postures.

The first prototype aimed to prove that lumber fabricated beds were viable. In addition, we investigated whether off-the-shelve material would meet the dimensions of the beds in a cost and time-effective manner. Figure 5A showcases prototype I, using a standard four-by-eight-foot oriented strand board (OSB). Prototype I met all the gross dimensions and was fabricated. This outcome supported our proof-of-concept and moved to the following iterations. Prototype III aimed to reduce the weight of the structure. We aimed for a single technician to arrange bed furrows. We devised a three-slotted cut-out design, removing about one-third of the weight. Note that only the side panels received the slotted cut-outs and the top OSB board remained whole. Prototype III focused on visually representing the real-world counterpart. Tan butcher paper was wrapped around the mock bed furrows to achieve the color scheme. This paper was combined with camouflage netting that mimicked the soil and foliage. The combination proved highly effective when photographed—the fourth prototype aimed at efficiently transporting the eight-foot section with a single technician. We created a dolly designed to fit underneath the backside of the structure. This dolly reduced the transportation time by half.



(A) (B)

(C) (D)

Figure 5. Replica prototype iterations: (A) Mock Bed Furrow Ideation, (B) Mock Bed Furrow prototype II CAD drawing, (C) Mock Bed Furrow II, (D) Mock Bed Furrow III.

Simulation layout and berry density

Equipment layout and berry density needed alignment with real-world counterparts to achieve simulation accuracy. For our purposes, layout refers to the setup of bed furrows and harvest aid. Two metrics, picking distance and delivery distance, were of interest. Picking distance represents the distance advanced during the picking task, while delivery distance means the distance traveled to drop off the completed tray. To facilitate the logistics of a single operator, we measured berry density as the number of completed trays per foot. Like previous equipment, we aimed to represent the biomechanics accurately. Due to equipment constraints (bed furrows, harvest aid) and available facilities, our metrics were focused on 16-foot sections of picking.

We began by collecting real-world benchmarking metrics from the Peng and colleagues (2020) study: picking advancement, picking time, and delivery speed. An additional metric, delivery time, was taken from the author's previous study on time. Altogether, we derived picking distance, delivery distance, and berry density (Table 2). In addition, below are the equations used to derive the values. It is important to note that berry density is in terms of bed furrows. The simulation comprised four-bed furrows, which conveniently matched the four-minute picking time. Therefore, berry density was set to three containers per eight feet of bed top furrow.

$$Picking\ Time\ x\ Picking\ Advancement = Picking\ Distance \quad (1)$$

$$Delivery\ Time\ x\ Delivery\ speed = Delivery\ Distance \quad (2)$$

$$12\ containers\ \div Picking\ Time = Picking\ Rate \quad (3)$$

Table 2

Duty Cycle Metrics

Metric	Value	Source
Delivery Time	12 s	Author
Delivery Speed	4.6 ft/s	
Picking Time	240 s	Peng et al., 2020
Picking Advancement	0.075 ft/s	
Picking Distance	18 ft	Derived
Delivery Distance	55 ft	Derived
Picking Rate	3 containers per min	Derived
Berry Density	3 container per bed	Derived

Figure 6. Simulation layout.

Several prototypes simulating the harvest aids were considered. An earlier prototype was built (Figure 7), which is designed to allow for simulated continuous picking. Plants and fruit distribution of the simulated beds were based on field observations.

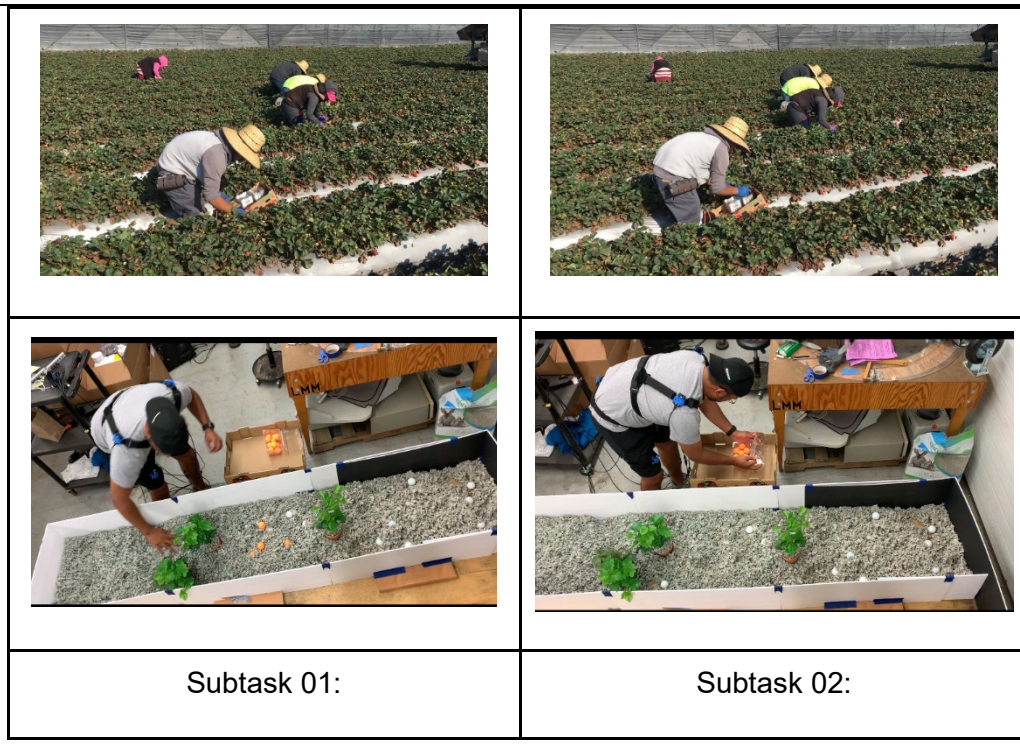


Figure 7. Earlier system for simulated harvesting tasks, which allows for continuous picking.

A preliminary analysis was conducted on workers in the field assuming stooped postures when using the multi-person harvest aid. Stooped postures of six workers were documented during the harvest phase, and non-productive times were assessed for the multi-person harvest aid (see Figure 8a and b). Average stooped posture angle among six observed workers was 67 degrees (11.7 std. dev.), and average non-productive time was 24.3 seconds (10.8 std. dev.).

Figure 8. (a) Estimated “stooped posture” angle (60 degrees) during harvesting, and (b) estimated non-productive time (21 seconds).

Biomechanical Assessment Study

The research team piloted several biomechanical measurement approaches to capture various biomechanical parameters from subjects during the simulated harvesting tasks. Various objective means to assess postural loads during harvesting were considered, including use of a multi-segment 3-D sensing system to capture various body postures during simulated harvesting (Figure 7-bottom). However, the system had several inconsistencies and multiple malfunctions; therefore, we deemed it to be impractical to use.

This led to the development of a wireless motion capture system. This custom system consists of an inertial measurement unit (IMU) and an analysis program. The search for potential IMU sensors concluded with a Yost Inc. Bluetooth Datalogger. It was cost-effective, python compatible, and proven compared to other models. YEI-sensors saved $2,000 compared to the 12M SXT2 inertial measurement unit. Moreover, the sensors provided an application program interface (API) for python. This API capacity would allow for the development of custom data analysis. Furthermore, a study by Khsoro-Anjom confirmed proof of concept using Yost Inc. YEI-sensors were used for trunk flexion tracking (Khorso-Anjom et al., 2014).

The final iteration of the capture system met all the requirements. For example, setup and operation can be handled with a single interaction. Plus, the sensor can run for approximately six hours before needing to be charged.

Python was used to develop custom programming to process and analyze the IMU data. Our aims for the program were: (i) import Euler angles, ii) calculate LFA, (iii) output analysis (figures and charts), and (iv) batch process two IMU sensors from 10-minute trial sessions. These aims produced a custom Python program leveraging libraries such as Numpy, Pandas, and SciPy. However, the program's cornerstone was a custom function applying the kinematic and linear algebra principles described in the Khosro-Anjom et al., 2014 paper. Once the program was free of significant errors, accuracy and precision testing were carried out.

Methods

Participants

A total of six subjects participated in the experiment. Participants were recruited from the University of California, Davis community. Table 3 summarizes subject demographics. To be eligible for the study, participants must be at least 18 years old and have no history of lower back injury. Before the simulated harvest, all participants completed a waiver detailing the risk and expectations of the study. After the waiver, a video detailing the real-world strawberry harvest played next. The instructions concluded with a technician's demonstration of the mock harvest. Participants also had the opportunity to sample the mock harvest for up to 5 minutes to ensure physical capacity before the trial. At that time, participants were asked for verbal confirmation to continue.

Table 3

Subject Demographics

No.	Subject No.	Height (in)	Weight (lbs)	Age (yrs)	Sex
1	1647	65	177	33	Male
2	1710	72	203	30	Male
3	4431	68.5	176	66	Male
4	6880	67	145	30	Female
5	7976	73	236	56	Male
6	8595	69.5	225	26	Male
-	Average	69	194	40	-

Apparatus

The experimental trials had two conditions following real-world picking measurements. These conditions will elucidate the relationship between machine settings (delivery distance) and lumbar response (biomechanics variables). Listed in Table 2, the specifications of the two-delivery distance, picking, and calculations are given in equations 1-3.

The first step in the experimental trials was securing the harness supporting the IMU sensors. Before placing the belt and vest on the subjects, a single sensor was taped to each piece of the harness. Technicians helped subjects into the harness and ensured proper fit. Moreover, technicians checked T10 and L5/S1 sensor placement (Figure 9). The studies arranged all equipment to mimic a real-world setting.

Figure 9. Sensor Harness

Furthermore, the study used four mock bed furrows to provide 16 feet of picking distance (Figure 10). The four mock beds ensured picking from either side as the subject advanced along the furrow. Note that the 16 feet align with the berry density calculations presented earlier. Moreover, the harvest aid replica was set directly in line with the last bed furrow. The Replica (Figure 11) was set (delivery distance) according to the nominal (55 ft) or modified (33 ft) testing condition. The study used a distance wheel to measure the last bed furrow to the docking platform of the Replica. Traffic cones were preset to mark distances. These markers helped to reduce the adjustment time between trial conditions.

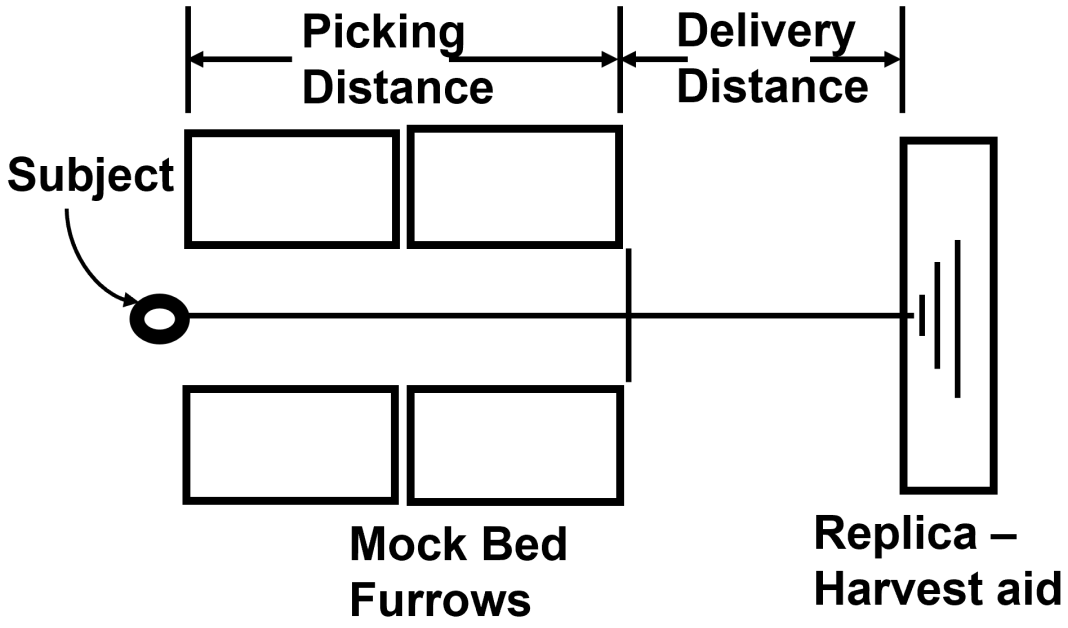


Figure 10. Layout schematic.

Figure 11. Replica docking platform.

Procedure

The experiment consisted of two test conditions with a 15-minute break between them. Two studies served as the reference to establish the nominal condition. The first was conducted by Peng et al., 2020 and the second was a time study based on site-visit footage taken. The analysis determined that the nominal walking condition (base delivery distance) was 55 feet. Table 4 below summarizes the delivery times during the site visit.

Table 4

Time Motion Study of Harvest Aid

	n	Mean	SD	Skewness	Kurtosis

Delivery Time	6	24.3 sec	10.8	1.8	4.1
Trunk Flexion	6	67.2 deg	11.8	1.1	2.2

Note: Data set did not pass the normality testing

We selected a 40% reduction for the modified condition to boost measurable differences between conditions. Thus, the modified condition was set to a 33-foot delivery distance. Only five of the six datasets collected from the subjects were included in the analysis. However, the sample size for all the results below is four. This stems from collection errors resulting in incomplete datasets.

Data Analysis

LFA was the primary outcome variable to gain insights into the effects of delivery distance. Our first aim was to investigate if delivery distance changes affected the upper and lower limits of the LFA. Secondly, we investigated whether LFA impacts the percentage spent in the riskiest postures. We compared pre-trial versus post-trial LFA to test for change in LFA limits. The study leveraged Yost IMU data to address these questions.

Lumbar Flexion Angle

The sensors continuously output Euler angles until the end of the trial session. Data is sent via Bluetooth in real time to a nearby laptop. All data is processed using a custom Python script in the post. Once processed, the program moves to the next step and calculates the LFA. Following the calculation, the data was partitioned into three segments: the only user input needed. The segments reflect the pre-trial, post-trial, and harvest sections. The harvest segment is where the subject carries out the simulated picking. Once segmented, the program automatically finds the maximums during the pre-and-post-trial portions. These three maximums form an average when comparing pre-trial and post-trial lumbar flexion angles. The third segment, harvest, is used for the second aim.

Histograms

To investigate the second aim, we examined the percentage of time spent in four risk categories. These four categories were adopted from work by Pieter Coenen and colleagues (Coenen et al., 2013). Their study established the category thresholds adopted here. One important note is that our study measures lumbar flexion angle while they elected to use trunk flexion angle (TFA). The difference between LFA and TFA was assumed to be minimal and suitable for our study. As outlined earlier, the data is processed and then segmented into a harvest portion. Once segmented, the custom script automatically carries out a histogram analysis. Table 5 describes the four intervals.

Table 5

Lumbar Flexion Risk Categories

Category	Degree Limits
Neutral	0 < 30
Mid	30 < 60
Extreme	60 < 90
Very Extreme	90 <

**These categories have been adapted Coenen et al., 2013*

Rating of perceived exertion

The final metric used in this study was the rating of perceived exertion (RPE). Our goal was to supplement the quantitative data with subjective experience. We aimed to investigate the personal experience across different conditions. Furthermore, we aimed to explore if the inner experience tracked with the quantitative data. The Borg scale requires no hardware to conduct. However, instructions are needed to inform subjects of the 6-20 scale. Each subject had two total ratings collected. Measurements were taken immediately after post-LFA data collection.

With Microsoft excel, we tested for normality using: Q-Q plots, Skewness, and Kurtosis. All tests failed the normality, driving the use of non-parametric testing. To this end, we carried out a Wilcoxon signed-rank test. This additional test also was not statistically significant.

Results

Lumbar flexion limits

Figure 12 showcases the comparison of pre-trial versus post-trial lumbar flexion angle. Note that the population size for the between-group average is four. Nevertheless, both conditions showed an increase in LFA post-trial. Between both conditions, the nominal condition had the smallest difference between pre and post, 28 degrees. On average, the modified condition measured 35 degrees greater post-LFA than pre-LFA. Moreover, the nominal condition had a difference of 28 degrees.

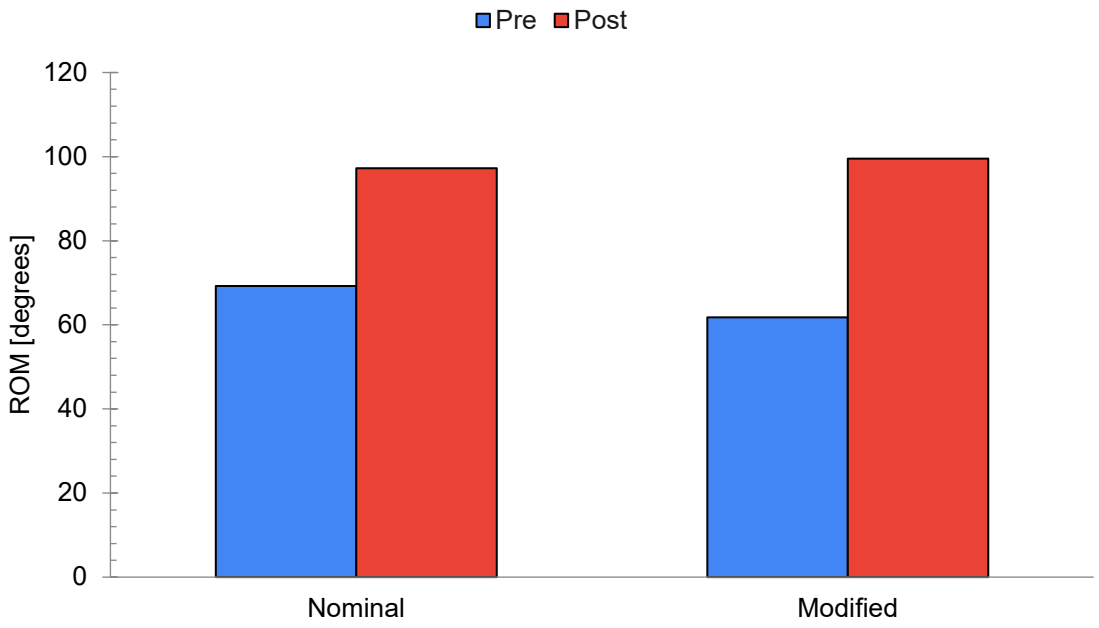


Figure 12. Pre- and post-trial lumbar flexion angles

Table 6

Lumbar Flexion Angle Averages

		Pre-trial		Post-trial		P-value	
	n	Mean	SD	Mean	SD	Within condition	Between condition
Nominal	4	69	25	97	47	0.080[a]	0.776[b]
Modified	4	65	20	100	37	0.072[a]	0.906[c]

Note: P-value for two-tailed t-test: (a) pre v post (b) pre v pre (c) post v post

Risk distribution

Figure 12 shows the overall distribution of time spent in any of the four risk categories during the harvest phase. The mid and extreme postures accounted for 85% of the distribution for both conditions. The mid risk was the single largest category for both conditions. One substantial difference found was the percentage of time spent in mid versus extreme. For example, in the nominal case, 56% of the time was spent in the mid category. While in the modified case, mid accounted for 48% of the time. Interestingly, a 10% increase in extreme posture was found in the modified case compared to the nominal. Refer to Table 7 for a complete breakdown of the distribution of all four categories.

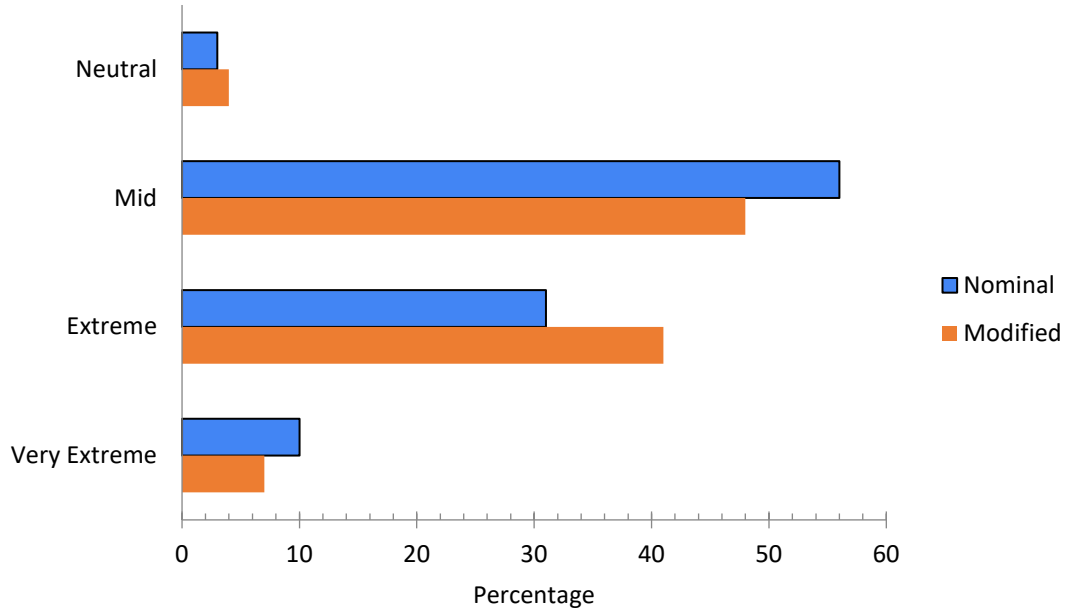


Figure 13. Risk Distribution during harvest phase

Table 7

Summary of Observational Risk Categories

Condition	Neutral	Mid	Extreme	Very Extreme
Nominal	3 %	56 %	31 %	10 %
Modified	4 %	48 %	41 %	7 %

Subjective Response

The final metric used in this study was the rating of perceived exertion (RPE). This metric analyzed the subjective experience of both conditions. The average RPE rating across subjects for the nominal case was 11, while the modified case reported 10.6. This dataset did not pass the normality test; therefore, the Wilcoxon signed rank test was also applied. This test also reported no statistical difference.

Table 8

Rating of Perceived Exertion Summary

	Nominal		Modified		
n	Mean	SD	Mean	SD	P-Value

5	11	2	10.6	1.52	0.442

Note: P-value is for a Wilcoxon singed rank test

Personal Harvesting Aids

Related to the personal harvesting aid, Professor Vougioukas' team built a novel device that can be snapped on to a standard picking cart, and can measure the weight of the harvested strawberries in real-time, as the picker fills up the tray with strawberries (Figure 14).

Figure 14. New personal harvesting aid.

Professor Vougioukas' team also updated several versions of the personal robot harvest aid (through funding from USDA). The earlier two major versions were small-footprint robots (12 inches wide) that could fit inside a single furrow (Figure 15 left). A third version was developed that had active balance control (Fig. 15 right). The personal harvest aid can be used with a standard strawberry picking cart. The system measures the harvest weight and is linked to a GPS module to produce yield maps.

Figure 15. Personal harvest aids (robots) without (left) and with (right) active balance control.

Professor Vougioukas' team also updated the version of the personal robot harvest aid, which straddles beds for improved stability in the field (Figure 16).

Figure 16. Latest collaborative robot.

A simulator was developed that models all crew harvest activities and robot team activities (Fig. 17). A new modeling framework was developed for human-robot collaboration during harvesting, using a hybrid systems formalism that combines discrete dynamics (Finite State Machines) with continuous dynamics (picker-robot motions and crop/mass transfer). The simulator was calibrated using data from field experiments.

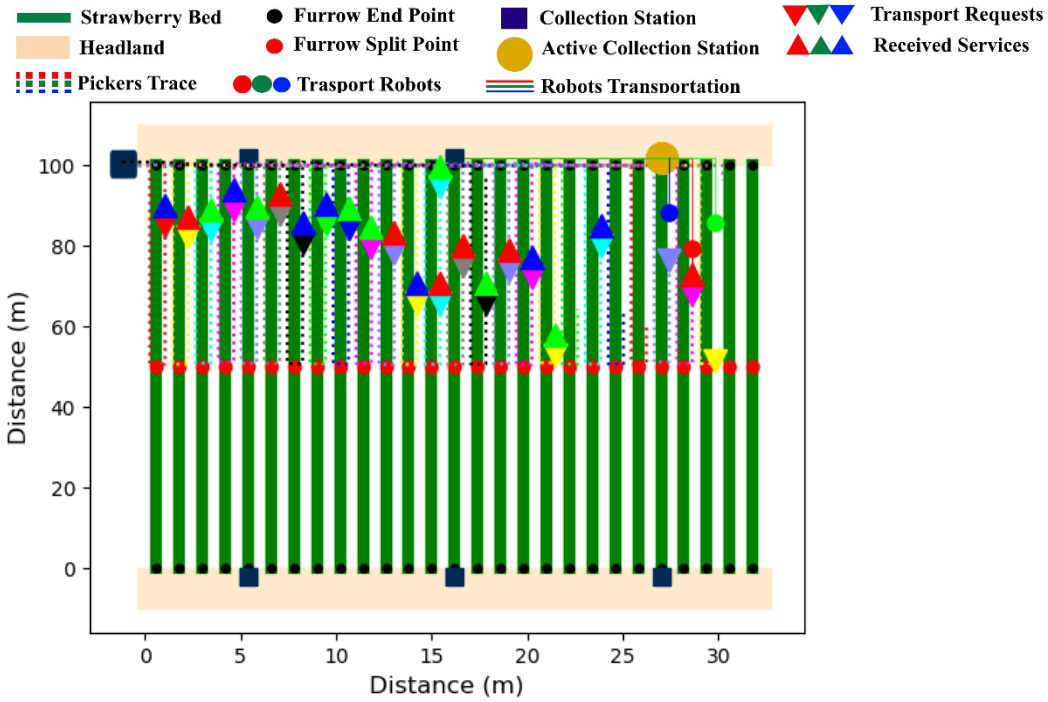


Fig. 17. Visualization of simulation platform in robot-aid harvesting mode: nine human pickers with the collaboration of three transport robots harvest for about 60 min. (dimensions are not scaled for the purpose of illustration).

Professor Vougioukas' research team conducted testing in the field for the novel device that can be snapped onto a standard picking cart and can measure the weight of the harvested strawberries in real-time, as the picker fills up the tray with strawberries (Figure 14). The newest version of the robot/personalized picking system can be used with a standard strawberry picking cart. The system measures the harvest weight and is

linked to a GPS module to produce yield maps. The harvest-aiding system, comprising seven instrumented picking carts and two mobile robots, was evaluated with a crew of six professional pickers in a commercial field near Lompoc, CA. Over two days, the mean harvesting efficiency of the co-robotic harvesting was approximately 12% higher, compared to that of manual harvesting (Figure 18). In fields with higher yields, efficiency increases and corresponding labor savings can reach up to 25%, according to results from simulations.

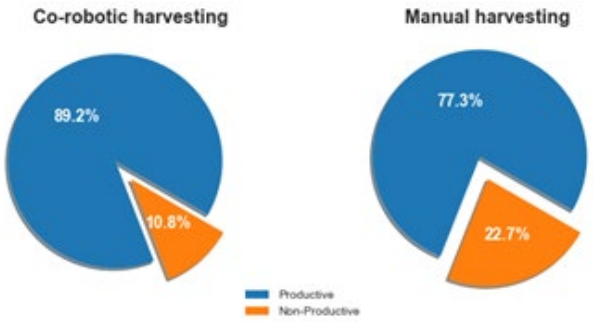


Figure 18. Labor savings comparison between co-robotic harvesting and traditional manual harvesting.

The results from the previous report period were analyzed, and a scientific publication was submitted and published in a high-impact peer reviewed journal (see outputs). In 2022, we started to explore the possibility of programming the robots for more equitable service rather than maximum-efficiency service. The robots offer a shared resource to the picker crew, and they have been programmed to minimize the overall time it takes for the entire crew to harvest a field, i.e., maximize the crew's harvest efficiency. Farmworkers' picking speeds vary, depending on age, skill, fatigue, and other factors. To maximize efficiency, the optimization software tends to serve fast pickers more frequently, which translates into fast pickers harvesting more rows and making more money. To program the robots for more equitable service, and potentially less taxing approach on the musculoskeletal system, algorithms were developed to minimize the variance in the improvement of the efficiency of all pickers or minimize the Theil index of the workers' incomes from the harvested trays. Preliminary simulation results showed that it is possible to increase service equity among the harvesting crew without penalizing the overall harvest efficiency. Further theoretical analysis and field experiments would be needed to explore the utility and acceptance of such robot programming policies in practice.

B.3. Competitive Revisions/Administrative Supplements

Year 6 – additional year of funding through NIOSH. See B2 for accomplishments associated with Year 6 activities.

B.4. What opportunities for training and professional development did the project provide?
Not applicable

B.5. How did you disseminate the results to communities of interest?
The project's results have been presented at the center's annual retreat, which was attended by stakeholders and growers, some of whom have offered practical guidance to the project and potential access to strawberry growers. Similarly, the project was presented to the center's External Advisory Board, and the members expressed support for the project and will help identify potential growers to collaborate with. Furthermore, the California Strawberry Commission is very interested in the results of this project, which will be shared with them. The project and its results have been shared with many stakeholders through multiple presentations. The results will also be shared with the center's Outreach Team for dissemination among farmworkers and farmers.

B.6 - What do you plan to do during the next reporting period to accomplish the goals?
Not applicable

C. PRODUCTS

Publications, conference papers, and presentations

Publications

2022

Peng, C., Vougioukas, S., Slaughter, D., Fei, Z., Arikapudi, R. (2022) A strawberry harvest-aiding system with crop-transport co-robots: Design, development, and field evaluation. Journal of Field Robotics 39(8):1231-1257. https://doi.org/10.1002/rob.22106

Presentations

2022

Fathallah, F.A. (2022). Ergonomics in Labor-Intensive Agriculture: Research, Interventions, and Outreach. Presentation at the 2022 Puget Sound HFES Annual Symposium.

Fathallah, F.A. (2022). California Labor-Intensive Agriculture: Musculoskeletal Disorders Risk Factors and Interventions. Presentation at the 2022 Postharvest Technology Center's Emerging Technologies. UC Davis. May 23.

2020

Fathallah, F.A. and Vougioukas, S. Personal Collaborative Robots in Agriculture (Virtual). Robotics Track, Session on Emerging Applications. ErgoX Symposium- Virtual/Chicago, IL. October 14, 2020. 40 attendees.

Peng, C., Vougioukas, S.G. (2020). System-level description and evaluation of a robot-aided strawberry harvesting system. ASABE Annual International Meeting. Omaha, Nebraska. Presentation #2000446.

2019

Fathallah, F.A. (2019). Presentation. Potential Ergonomic Benefits of Personal Collaborative Robots in Strawberry Harvesting, NIOSH Expanding Research Partnerships, 2019 Webinar Series. Looking to the Future: Occupational Robotics Safety and Health Research at NIOSH.

Fathallah, F.A. and Duraj V. (2019). Design Solutions for Prevention of Musculoskeletal Disorders in Agriculture. Thematic Session: Prevention through Design in New Technologies. NIOSH Western Agriculture Safety and Health Conference - Cultivating Collaborations. Seattle, WA. August 7-9.

Munguia V., Fathallah F.A., Vougioukas S., and Duraj V. (2019). Evaluation of Mechanical and Robotic Strawberry Harvest-Aids. Poster Presentation at the NIOSH Western Agricultural Safety & Health Conference: Cultivating Collaborations. Seattle, WA. August 7-9.

Peng, C., Vougioukas, S.G. (2019). Scheduling performance of harvest-aiding crop-transport robots under varying earliness in access to transport-request predictions. ASABE Annual International Meeting. Boston, Massachusetts.

2018

Seyyedhasani, H., Peng, C., Vougioukas, S.G., (2018). Efficient Dispatching of a Team of Harvest-aid Robots to Reduce Waiting Time for Human Pickers. ASABE Annual International Meeting. Paper # 1801715, Detroit, Michigan.

C.2. Website(s) or other Internet site(s) – include URL(s)
N.A.

C.3. Technologies or techniques
N.A.

C.4. Inventions, patent applications, and/or licenses
N.A.

C.5. Other products and resource sharing
N.A.

D. PARTICIPANTS

D.1. What individuals have worked on the project? Please include calendar, academic, and summer months.

Commons ID	S/K	Name	Degrees(s)	Role	Cal	Aca	Sum	Foreign	Country	SS

		Andrews, Teresa		Community Education Specialist 3	2.25					
		Duraj, Victor		Research and Development Engineer 3	27.89					
		Fathallah, Fadi		Professor FY	0.03					
		Fathallah, Fadi		Researcher FY	1.26					
		Hunter, Tyler		Jr. Specialist	11.34					
		Munguia, Vicente De Jesus		GSR		4.98				
		Prado, Kimberly Y		GSR		0.51				
		Vougioukas, Stavos George		Associate Researchers	0.05					
		Vougioukas, Stavos George		Researcher	0.25					

D.2 Personnel updates
N.A.

E. IMPACT

E.1 - What is the impact on the development of human resources, if applicable?
N.A.

E.2 - What is the impact the Public Health Relevance and Impact? The investigator should address how the findings of the project relate beyond the immediate study to improved practices, prevention or intervention techniques, legislation, policy, or use of technology in public health.

Strawberry workers constitute the largest farmworker population in California. While maintaining acceptable productivity levels, implementing the guidelines developed in this study is expected to minimize the risk of low back disorders in this population of farmworkers. Similar approaches could be implemented in other labor-intensive harvesting of low-growing crops such as melons and leafy vegetables. Growers could implement new guidelines on deploying harvest aids in the fields, which minimizes the risk to the workers while maintaining acceptable productivity.

F. CHANGES

F.1 – Changes in approach and reasons for change, including changes that have a significant impact on expenditures
None

F.2 - Actual or anticipated challenges or delays and actions or plans to resolve them
N.A.

F.3 - Significant changes to human subjects, vertebrate animals, biohazards, and/or select agents
None

G. Special Reporting Requirements

G.1 Special Notice of Award Terms and Funding Opportunities Announcement Reporting Requirements
N.A.

G.2 Responsible Conduct of Research

N.A.

G.3 Mentor's Research Report or Sponsor Comments

N.A.

G.4 Human Subjects

G.4.a Does the project involve human subjects?
Yes

G.4.b Inclusion Enrollment Data

See attached

G.4.c ClinicalTrials.gov
N.A.

Does this project include one or more applicable clinical trials that must be registered in ClinicalTrials.gov under FDAAA?
N.A.

G.5 Human Subject Education Requirement
Are there personnel on this project who are newly involved in the design or conduct of human subject's research?
No

G.6 Human Embryonic Stem Cells (HESCS)
Does this project involve human embryonic stem cells (only hESC lines listed as approved in the NIH Registry may be used in NIH funded research)?
No

G.7 Vertebrate Animals
Does this project involve vertebrate animals?
No

G.8 Project/Performance Sites
University of California, Davis

G.9 Foreign Component
No

G.10 Estimated Unobligated Balance
N.A.

G.10.a Is it anticipated that an estimated unobligated balance (including prior year carryover) will be greater than 25% of the current year's total approved budget?
No

G.11 Program Income
Is program income anticipated during the next budget period?
No

G.12 F&A Costs
Is there a change in performance sites that will affect F&A costs?
No

I. OUTCOMES

I. Provide a concise summary of the outcomes or findings of the award, written for the general public in clear and comprehensible language, without including any proprietary, confidential information or trade secrets

Note: project outcome information will be made public in NIH RePORTER

In this project, we investigated the effects of strawberry harvest aids on the biomechanical response of workers. We built a simulated harvest aid system that replicates field conditions and conducted field observations and controlled experiments. We monitored workers' productivity in actual strawberry picking operations when using a personal collaborative-robotic system as well as spinal posture when performing a simulated strawberry picking using various harvest aids and picking conditions. The main findings of the project were:

- The harvest aid system built for this study provides an adequate system for replicating field picking conditions.
- The biomechanical response of the spine is affected by how far the harvest aid system is away from the worker, with increased walking distance resulting in reduced lumbar flexion angle and the amount spent in high-risk postures.
- The collaborative robot system investigated in this study seems to provide a substantial increase in worker productivity.
- The robot optimization software tends to serve fast pickers more frequently, which translates into fast pickers harvesting more rows and making more money, creating a potential for inequity among workers.
- Preliminary simulation results of the robotic system showed that it is possible to increase service equity among the harvesting crew without penalizing the overall harvest efficiency. Follow up biomechanical confirmation is needed to assess the effects on worker.

Program Director/Principal Investigator (Last, First, Middle):

Inclusion Enrollment Report

This report format should NOT be used for data collection from study participants.

Study Title: Ergonomic and Biomechanical Eval of Mechanical and Robotic Strawberry Harvest-aids

Total Enrollment: 18 **Protocol Number:** 965026-7

Grant Number:

PART A. TOTAL ENROLLMENT REPORT: Number of Subjects Enrolled to Date (Cumulative) by Ethnicity and Race

Ethnic Category	Females	Males	Sex/Gender Unknown or Not Reported	Total
Hispanic or Latino	6	9		15 **
Not Hispanic or Latino	1	2		3
Unknown (individuals not reporting ethnicity)				
Ethnic Category: Total of All Subjects*	7	11		18 *
Racial Categories				
American Indian/Alaska Native		1		1
Asian	1	1		2
Native Hawaiian or Other Pacific Islander				
Black or African American				
White	2	3		5
More Than One Race				
Unknown or Not Reported	4	6		10
Racial Categories: Total of All Subjects*	7	11		18 *

PART B. HISPANIC ENROLLMENT REPORT: Number of Hispanics or Latinos Enrolled to Date (Cumulative)

Racial Categories	Females	Males	Sex/Gender Unknown or Not Reported	Total
American Indian or Alaska Native		1		1
Asian				
Native Hawaiian or Other Pacific Islander				
Black or African American				
White	2	3		5
More Than One Race				
Unknown or Not Reported	4	5		9
Racial Categories: Total of Hispanics or Latinos**	6	9		15 **

* These totals must agree.
** These totals must agree.

Western Center for Agricultural Health and Safety

Marc Schenker, Ph.D.

Project 4: Heat Illness Prevention in Farmworkers: Translation of Economic, Socio-Cultural, and Physiological Factors into Effective Interventions

B. ACCOMPLISHMENTS

B.1. What are the major goals of the project?

Despite major campaigns to reduce Heat Related Illness (HRI) in agricultural workers, deaths and illnesses still occur at a significantly higher rate compared to other workers exposed to hot environments. The causative factors are more complex than just a consideration of environmental, work intensity, and physiological components. Cultural and socio-economic factors unique to the largely immigrant pool of farmworkers are crucial considerations when looking for a way to reduce the prevalence of preventable HRI. Our overall goal is to translate existing quantitative and qualitative data from the California Heat Illness Prevention Study (CHIPS) on behavioral and physiological factors in California farmworkers into multi-faceted risk-reduction strategies that are culturally relevant and more effective than current preventive efforts. We intend to engage agricultural stakeholders from farm organizations and labor in a collaborative effort to understand the complexities of HRI and devise workable solutions the whole community can support. To aid this effort, we hypothesize that 1) an economic study of California farms will indicate previously discounted effects of HRI on human and production costs and thereby increase industry support of HRI programs, and 2) that electronic mobile phone applications can be devised to reduce the risk of HRI by assisting primary prevention, and secondly by incorporating sensors to prevent workers exhibiting early signs of HRI from becoming overtly ill. The combination of these elements will be used to devise new and practical HRI risk reduction strategies that can be integrated into training materials and other outreach efforts to the broad array of stakeholder audiences who have a role in preventing HRI among farmworkers.

Specific Aim 1: Develop culturally appropriate and effective strategies to reduce the risk of HRI in California agriculture.

Aim 1a: We will incorporate information from behavioral, cultural, and physiological factors from our current research and from SA 2, to create new, more effective strategies and training materials for HRI prevention. We will engage agricultural stakeholders in the development of these materials to ensure their wide acceptability.

Aim 1b: We will evaluate, refine, and distribute the new training materials to stakeholder audiences using appropriate media.

Specific Aim 2: Determine the economic costs and predict the benefits of reducing HRI in California agriculture. Using population level data and information from farms associated with our current HRI research, we will calculate the loss of productivity and the cost of contemporary levels of HRI in California agriculture. We will draw on wage practices and labor cost information from University of California Cooperative Extension (UCCE) cost studies for labor intensive crops and information on productivity and other impacts of heat illness from the sample farms.

Specific Aim 3: Develop mobile phone applications to implement both primary and secondary HRI prevention approaches in California agriculture.

Aim 3a: We will integrate algorithms of risk of HRI with mobile technologies to provide basic risk level predictions, indicate applicable regulation requirements and risk reduction suggestions. Using our current HRI research data, we will develop these algorithms incorporating site and population specific inputs relevant to the individual workplace.

Aim 3b: We will similarly develop algorithms for secondary risk reduction using previous research and sensors to assist with the evaluation of clinical (symptomatic) and sub-clinical heightened risk of

HRI in individuals. The outputs would deliver specific instructions and assist with alerting farm management and emergency responses.

Previous translational studies on this theme have developed work site interventions, but HRI still occurs with high frequency in agriculture. This project will add the dimension previously lacking, namely incorporating worker and employer buy-in to develop solutions and tailor education, training, and outreach to encompass their needs. Developing alerts and delivering real time information to the fields via mobile phone applications to the supervisors will bring HRI prevention into daily rather than occasional awareness. Because extreme heat events have become more frequent and are projected to increase with global climate change, our proposed translational research with culturally relevant solutions is both urgent and essential.

B.2. What did you accomplish under these goals?

Specific Aim 1

A total of six train-the-trainer (ToT) sessions reaching 118 supervisors of farmworkers were held in the Imperial Valley, Clovis, Stockton, St. Helena, and Modesto, California. An additional five supervisor training sessions (an abbreviated version of the ToT material) were held in the Salinas Valley. Trainings for workers have included 80 Spanish or Mixteco-speaking participants. The feedback (pre- and post-training quizzes and participant evaluations) were used to revise the training materials during Year 3 and once again during Year 4. After these revisions and updates based on the findings of the California Heat Illness Prevention Study (CHIPS), the training content was finalized and materials professionally designed and printed. Over 70,000 packets of printed heat illness prevention training materials have been mailed out. Short videos on the importance of heat-related illness in English and Spanish were posted to WCAHS's website and YouTube in 2020 and have received 897 views. Short videos in Spanish with information on water, shade, and rest breaks for HRI prevention were posted to YouTube in October 2022.

A preliminary analysis of the impact on heat illness in California's cannabis industry was added in Year 6. After assessment, existing administrative datasets were found inadequate to address this for several reasons: the recency of adult use legalization, lack of a specific industry code for cannabis for search purposes, and under-reporting of HRI. In addition, the majority of cannabis is grown illegally, and HRI would not be reported as an occupational illness. Participants in an ongoing study of cannabis worker health responded to questions about HRI, and one had experienced a single event of HRI. Other participants said it was occasionally a problem among cultivation workers but were largely more concerned about exposure to cold. The participants worked in the cooler areas of Northern California, so the extent of HRI in California cannabis farming in general remains uncharacterized.

Specific Aim 2

1. Local weather station data was combined with CHIPS data to estimate the association between production at the study farms and the maximum ambient temperature on the days of the field study. As production of commodities was not a measured variable, the length of the workday was used as a surrogate. An association between ambient temperature and number of hours worked was found, with a 10°C increase resulting in an average reduction of the workday by 50 minutes, independent of other variables in the model. When the maximum ambient temperature rose above 35°C (so triggering Cal/OSHA rules to provide more rest breaks and increased monitoring of workers to prevent HRI symptoms), the mean length of the work shift was reduced by 55 minutes independent of whether workers were acclimatized or not. The reduction in the length of workdays is most likely instigated by management and indicates reductions in productivity. Additionally, piece-rate participants worked on average 84 minutes less per day than hourly workers. Tree pruners and those hand-harvesting trees and vines worked significantly fewer minutes than were the average for other workers, by 51 and 48 minutes, respectively.
2. The relationship between work rate, environmental temperature, and core body temperature was investigated. Increased environmental temperature, work rate, male sex, and increased BMI were associated with increased core body temperature. Risk of HRI was exacerbated by work rate and environmental temperature despite farms following Cal/OSHA regulations for HRI prevention.

3. An analysis examined the relationship between heat exposure, worker compensation incentives, and physical activity level of hired crop workers. These data reveal behavioral patterns and correlations among the rate of physical activity, worker characteristics, tasks, and heat exposure. There is a non-linear response of worker activity to increasing heat exposure. Piece-rate pay arrangements are associated with an increase in average worker activity, but data do not show evidence of piece-rate pay arrangements associated with increased activity under extreme heat exposure. With moderate heat exposure, piece-rate pay arrangements increase worker activity, which may cause a higher potential risk of heat-related illness. However, under extreme exposure at high temperatures, piece-rate pay arrangements decrease worker activity compared to workers paid at an hourly wage rate. These results are complicated by the fact that piece-rate workers generally ended their work shifts earlier in the day (before temperatures reached their peak) compared to hourly workers.
4. In preparation: "How does environmental temperature affect farmworkers' work rates in the California Heat Illness Prevention Study (CHIPS)?" This analysis investigates the effect on work rate of environmental temperature in the previous 15-minute interval using a repeated measures regression for autoregressive data. An increase in temperature was associated with decreased work rate in the next interval. In addition, total time worked that day, age, and dehydration at the end of the workday were associated with work rate, as were gender, pay type (piece-rate vs. hourly), and having a BMI ≥25. The effects of pay type and BMI were modified by gender.

In general, analyses of these data reveal behavioral patterns and correlations among the rate of physical activity, worker characteristics, tasks, and heat exposure. There is a non-linear response of worker activity to increasing heat exposure. Piece-rate pay arrangements are associated with an increase in average worker activity, but data do not show evidence of piece-rate pay arrangements associated with increased activity under extreme heat exposure. With moderate heat exposure, piece-rate pay arrangements increase worker activity, which may cause a higher potential risk of heat-related illness. However, under extreme exposure at high temperatures, piece-rate pay arrangements decrease worker activity compared to workers paid at an hourly wage rate. These results are complicated by the fact that piece-rate workers generally ended their work shifts earlier in the day (before temperatures reached their peak) compared to hourly workers.

Specific Aim 3
A prototype of a mobile application to help supervisors reduce the risk of HRI in their farmworker crews was completed in 2017 and evaluated by two groups of users in 2018. The collaborator, Wizeline, added additional updates based on Cal/OSHA's heat illness prevention regulations including alerts for heat waves, when the ambient temperature exceeds 35°C, and other essential reminders and planning options. Key interviews and other assessments of the app based on real-time use in the fields were completed in 2020.

After detailed testing in 2021, it was decided that the tool was very similar to the latest update of OSHA-NIOSH's Heat Safety Tool App. Due to this similarity and limited capacity for long-term maintenance of an app the remaining resources were reallocated to printing and promotion of the new printed educational material tool kit.

B.3. Competitive Revisions/Administrative Supplements
Year 6 – additional year of funding through NIOSH. See B2 for accomplishments associated with Year 6 activities.

B.4. What opportunities for training and professional development did the project provide?

A total of six train-the-trainer (ToT) sessions reaching 118 supervisors of farmworkers were held in the Imperial Valley, Clovis, Stockton, St. Helena, and Modesto, California. An additional five supervisor training sessions (an abbreviated version of the ToT material) were held in the Salinas Valley. As these supervisors go on to train the workers they supervise, this model amplifies the training capacity of our outreach ad will allow up to 1,000 workers to be trained using the latest materials

This project provided support for four early career researchers and 10 students.

B.5. How did you disseminate the results to communities of interest?
The video and training materials were used in nine trainings: three for 54 English-speaking supervisors, two for 51 Spanish-speaking supervisors, three for 44 Spanish-speaking workers, and one for 36 Spanish- and Mixteco-speaking workers. Each attending supervisor received the new package of materials to use for future trainings. Feedback has been overwhelmingly positive. In total, we have mailed out over 70,000 packages of printed materials. Both the video and training materials have been featured in NIOSH's monthly eNews as well as in the WCAHS newsletter. Short videos on the importance of heat-related illness in English and Spanish were posted to WCAHS's website and YouTube channel in 2020 and have received 897 views. Short videos in Spanish with information on water, shade, and rest breaks for HRI prevention were posted to YouTube in October 2022.

We are using the ToT model to amplify the trainings on the prevention of HRI to the wider farmworker population. The trainings are held in Spanish, as both supervisors and their supervisees are more comfortable using their native language. Last year, this targeted method allowed around 1,000 farmworkers to be trained in California. After we have completed modifying the trainings, we will work with sociobehavioral and media specialists to broadcast the messages across the Latino farmworking community.

The video has been featured in the NIOSH eNews monthly newsletter as well as the WCAHS newsletter. The manuscript assessing compliance with, and effectiveness of Cal/OSHA regulations is accepted pending revisions and will be featured in the NIOSH Research Round. In addition, the manuscript, video, training materials, and app were featured in the NIOSH Science Blog in summer 2022. We highlighted key findings and work done to date at the UC Merced Farmworker Health Research Conference this spring. This conference came about because farmworker communities have recently gotten an influx of requests to participate in research on farmworkers' health (due to COVID-19) and provided an opportunity for us to share our experiences, emphasize key points, and discuss gaps to be addressed by future research.

B.6 - What do you plan to do during the next reporting period to accomplish the goals?
N.A.

C. PRODUCTS

C.1. Publications, conference papers, and presentations

Publications

2022

Olivares LV, Engle-Stone R, Arnold CD, Langer CE, Schenker MB. Anemia, Weight Status, and Fatigue Among Farmworkers in California: A Cross-Sectional Study. *J Occup Environ Med*. 2022 Aug 1;64(8):e459-e466. doi: 10.1097/JOM.0000000000002578. Epub 2022 Jun 11. PMID: 35673250; PMCID: PMC9377492.

2021

Pan Q, Sumner DA, Mitchell DC, Schenker M. Compensation incentives and heat exposure affect farm worker effort. *PLoS One*. 2021 Nov 2;16(11):e0259459. doi: 10.1371/journal.pone.0259459. PMID: 34727122; PMCID: PMC8562852.

Langer CE, Mitchell DC, Armitage TL, Moyce SC, Tancredi DJ, Castro J, Vega-Arroy AJ, Bennett DH, Schenker MB. Are Cal/OSHA Regulations Protecting Farmworkers in California from Heat-Related Illness? *J Occup Environ Med*. 2021;63(6):532-539.

2020

Moyce S, Armitage TL, Mitchell DC, Schenker MB. Acute kidney injury and workload in a sample of California agricultural workers. *Am J Ind Med*. 2020; 63:258-68. DOI: 10.1002/ajim.2307

Moyce S, Mitchell DC, Vega-Arroyo A, Schenker MB. Hydration choices, sugary beverages, and kidney injury in agricultural workers in California. *J Nursing Scholarship*. 2020. DOI: 10.1111/jnu.12561

Manuscripts under development

Langer CE, Armitage TL, Beckman S, Tancredi DJ, Mitchell DC, Schenker MB. How does environmental temperature affect farmworkers' work rates in the California Heat Illness Prevention Study (CHIPS)? Target journal: Journal of Occupational and Environmental Medicine.

Presentations
2022

Schenker MB. "Agricultural Health: Perspectives on Heat Illness and Immigrant Health." Western Occupational & Environmental Medical Association Conference. Napa, California. October 8, 2022.

2020

Schenker MB. "Heat stress risks and outcomes among California farmworkers." WCAHS Seminar Series (online). November 2, 2020.

Abstracts
2021

CE Langer and MB Schenker. "California Heat Illness Prevention Study (CHIPS): Main Findings and Future Implications." UC Merced Farmworker Health Research Conference. April 9, 2021.

L Olivares, R Engle-Stone, CE Langer, MB Schenker. "Relationship between Anemia and Weight Status Among Agricultural Workers in California." UC Merced Farmworker Health Research Conference. April 9, 2021.

C.2. Website(s) or other Internet site(s) – include URL(s)
https://aghealth.ucdavis.edu

YouTube Videos:
Heat-Related Illness Prevention on the Farm Benefits Everyone: https://youtu.be/K6t6fp7N3-4
La prevención de enfermedades relacionadas con el calor beneficia a todos: https://youtu.be/1MP_XBrMnEk
Trabajando en el Calor en CA: Agua (Working in the Heat in CA: Water): https://youtu.be/Tm6XmWnRTwU
Trabajando en el Calor en CA: Descansos (Working in the Heat in CA: Rest): https://youtu.be/cTlXmq4GwB4
Trabajando en el Calor en CA: Sombra (Working in the Heat in CA: Shade): https://youtu.be/kw0F_hcWIY8

C.3. Technologies or techniques
Not Applicable

C.4. Inventions, patent applications, and/or licenses
Not Applicable

C.5. Other products and resource sharing

Data used for analyses by Pan et al. (2021) and Olivares et al. (2022) were made publicly available alongside open access publications.

D. PARTICIPANTS

D.1. What individuals have worked on the project? Please include calendar, academic, and summer months.

Commons ID	S/K	Name	Degrees(s)	Role	Cal	Aca	Sum	Foreign	Country	SS
		Andrews, Teresa		Community Education Specialist 3	10.22					
		Armitage, Tracey L		Research Data Analyst 2	2.84					
		Avila, Carina Isabel		Student 3	0.17					
		Bechman, Stella Fay		Survey Researcher 3	3.99					
		Castro Javier		CMTY HEALTH PRG SUPV	1.18					
		Flores, Isabel		Community Education Specialist 3	0.2					
		Langer, Chelsea E.		Research Grant Program Officer 3	21.52					
		Mitchell, Diane C.		LAB RSCH SUPV 2	0.5					
		Mitchell, Diane C.		RSCH DATA ANL 3	1.08					
		Mitchell, Diane C.		SRA 5	7.47					
		Olivares, Leslie V		Community Education Specialist 3	2.5					
		Schenker, Marc B.		Recall Faculty	1.85					
		Schilli, Kara M.		Community Education Specialist 3	3.85					
		Shira, Rebecca E.		Lab Research Supervisor 2	2.95					

		Singh, Rajwant		Student 3	2.61					
		Tyree-Hageman, Jennifer L.		GSR-FULL FEE REM	0.45					

D.2 Personnel updates
N.A.

E. IMPACT

E.1 - What is the impact on the development of human resources, if applicable?
Not Applicable

E.2 - What is the impact the Public Health Relevance and Impact? The investigator should address how the findings of the project relate beyond the immediate study to improved practices, prevention or intervention techniques, legislation, policy, or use of technology in public health.

The findings of this study are relevant to the approximately 829,000 farmworkers in the state of California. The results of analyses in the publications resulting from this study can be used to guide and assess heat related illness prevention regulations in California, as well as to guide future research on occupational heat related illness.

The materials developed, namely the video and training packet, facilitate the training process for supervisors to educate their workers on how to be safe in the heat.

F. CHANGES

F.1 – Changes in approach and reasons for change, including changes that have a significant impact on expenditures
Not Applicable

F.2 - Actual or anticipated challenges or delays and actions or plans to resolve them
Not Applicable

F.3 - Significant changes to human subjects, vertebrate animals, biohazards, and/or select agents
Not Applicable

G. Special Reporting Requirements

G.1 Special Notice of Award Terms and Funding Opportunities Announcement Reporting Requirements
Not Applicable

G.2 Responsible Conduct of Research

Not Applicable

G.3 Mentor's Research Report or Sponsor Comments
Not Applicable

G.4 Human Subjects
G.4.a Does the project involve human subjects?
Yes

G.4.b Inclusion Enrollment Data
Not Applicable

G.4.c ClinicalTrials.gov
Not Applicable

Does this project include one or more applicable clinical trials that must be registered in ClinicalTrials.gov under FDAAA?
No

G.5 Human Subject Education Requirement
Are there personnel on this project who are newly involved in the design or conduct of human subject's research?
No

G.6 Human Embryonic Stem Cells (HESCS)
Does this project involve human embryonic stem cells (only hESC lines listed as approved in the NIH Registry may be used in NIH funded research)?
No

G.7 Vertebrate Animals
Does this project involve vertebrate animals?
No

G.8 Project/Performance Sites
Not Applicable

G.9 Foreign Component
Not Applicable

G.10 Estimated Unobligated Balance
Not Applicable

G.10.a Is it anticipated that an estimated unobligated balance (including prior year carryover) will be greater than 25% of the current year's total approved budget?

G.11 Program Income
Is program income anticipated during the next budget period?
Not Applicable

G.12 F&A Costs
Is there a change in performance sites that will affect F&A costs?
Not Applicable

I. OUTCOMES

I. Provide a concise summary of the outcomes or findings of the award, written for the general public in clear and comprehensible language, without including any proprietary, confidential information or trade secrets

Note: project outcome information will be made public in NIH RePORTER

The video and training materials were used in nine trainings: three for 54 English-speaking supervisors, two for 51 Spanish-speaking supervisors, three for 44 Spanish-speaking workers, and one for 36 Spanish- and Mixteco-speaking workers. Each attending supervisor received the new package of materials to use for future trainings. Feedback has been overwhelmingly positive. In total, we have mailed out over 70,000 packages of printed materials. Both the video and training materials have been featured in NIOSH's monthly eNews as well as in the WCAHS newsletter. Short videos on the importance of heat-related illness in English and Spanish were posted to WCAHS's website and YouTube in 2020 and have received 897 views. Short videos in Spanish with information on water, shade, and rest breaks for HRI prevention were posted to YouTube in October 2022.

There were several findings based on analyses of the study data:

- During hotter weather, work shift lengths were shorter. When the ambient temperature was greater than 35°C (95°F) the average workday is 55 minutes shorter. This was most likely based on decisions by managers and would reduce worker productivity.
- Workers who are paid piece-rate have higher activity levels than workers paid hourly at lower temperatures, but at temperatures over 35°C (95°F) piece-rate workers reduce their activity to below that of hourly workers. Piece-rate workers increase the rate of activity during moderate temperatures, which may cause a greater risk for HRI; however, flexibility about pay arrangements depending on the temperature may help prevent HRI.
- When considering environmental heat and activity level throughout the workday, hotter temperature in the previous 15-minute interval is associated with a lower activity level. The work rate was also affected by the worker's age, gender, BMI, and dehydration at the end of the workday.
- Even when farms are following Cal/OSHA's heat-related illness prevention regulations for worker training and hydration, workers experience risk of HRI measured by elevated core body temperature. Risk factors for elevated core body temperature are higher ambient temperatures, being male, having a higher work rate, and having a higher BMI.
- Anemia can cause fatigue and reduced productivity. Anemia was rare among study participants and not associated with reporting fatigue at work. Most workers participating in the study had a BMI categorized as overweight or obese.

Western Center for Agricultural Health and Safety

Edward R. Atwill, Ph.D.

Project 5: Heat Illness Prevention in Farmworkers: Reducing Occupational Exposure to Zoonotic Pathogens in California Dairy Workers

B. ACCOMPLISHMENTS

B.1. What are the major goals of the project?

The majority of California dairy farms have a high prevalence of endemic zoonotic pathogens in their cattle, namely *Cryptosporidium parvum*, E. coli O157:H7, *Salmonella enterica* subsp. *enterica*, L*isteria monocytogenes*, and *Campylobacter jejuni*. Moreover, there are specific cohorts of cattle with higher prevalence and higher intensity of fecal shedding of those pathogens. Contact with these highly infectious cattle substantially elevates the risk of zoonotic transmission to farmworkers, particularly if farmworkers employ risky personal behaviors, such as improper use of protective equipment, are assigned job tasks that result in sustained fecal exposure, and work on dairy farms with poor safety culture or deficient engineering or administrative controls. To our knowledge, identification of these nodes of high occupational exposure to zoonotic pathogens has not been conducted previously for western animal agriculture overall and specifically for California's large dairy industry in a comprehensive manner; the lack of this surveillance has likely led to unnecessarily high levels of exposure to zoonotic pathogens among farmworkers and the associated human risk of enteric infection. This project will facilitate substantial reduction in farmworker occupational exposure to these enteric pathogens and thereby help reduce the annual incidence of these occupational diseases in California dairy farmworkers. The goals for this project are to develop the necessary zoonotic pathogen exposure data to identify worker behavior and protective equipment, along with employer-level controls that will mitigate these risks and develop and disseminate training materials that will assist dairy farm workers and their employers to reduce occupational exposure to zoonotic infectious pathogens commonly shed by California dairy cattle. These goals, outcomes, and impacts will be achieved by addressing the following specific aims:

Specific Aim 1. Quantify high-risk bacterial and protozoal zoonotic pathogens shed by infected California dairy cattle that can result in zoonotic pathogen infections in farmworkers with direct contact with cattle or their manure. Previous epidemiological surveys will be combined with new microbiological data from our project to characterize specific cohorts of dairy cattle that exhibit a higher prevalence and higher intensity of fecal shedding of *Cryptosporidium parvum*, E. coli O157:H7, *Salmonella enterica* subsp. *enterica*, *Listeria monocytogenes*, and *Campylobacter jejuni*.

Specific Aim 2. Identify hierarchical clusters of high occupational exposure to zoonotic pathogens for dairy farm workers. We will identify combinations of worker occupational task, use of protective equipment, specific personal behaviors, and psychosocial factors, along with engineering and administrative controls associated with dairy farming that collectively affect the risk of sustained exposure to bovine zoonoses for farmworkers, using both traditional epidemiological methods and novel network analysis algorithms developed by our research team. To bolster the validity of these findings, these identified clusters of high exposure risk will be cross-referenced against each farmworker's history of clinical symptoms consistent with enteric infection from the studied pathogens (*C. parvum*, E. coli O157:H7, etc.). These combinations of worker-level and owner/manager-level factors that cause these clusters of high exposure risk will be targets for our worker and owner/manager training in Specific Aim 3.

Specific Aim 3. Develop and disseminate recommendations for reducing zoonotic exposure to dairy workers, farm owners and managers, and allied organizations by conducting outreach and training in California, Nevada, and Arizona. The outreach and training activities, done in collaboration with the WCAHS Outreach Core, will magnify the impact of this project and help promote zoonotic disease prevention among our large population of California dairy farmworkers, along with key dairy regions in Nevada (Fallon area) and Arizona (greater Phoenix area). Outcomes from this project will include a detailed assessment of how animal

infection patterns—when combined with high-risk occupational tasks, inadequate personal protective behaviors or equipment, and lack of proper engineering or administrative controls by the employer/owner—result in significant risk of zoonotic pathogen exposure. The knowledge gained and training materials developed for zoonotic disease risk reduction will be readily applicable to farmworkers on dairies located not just in California, but also throughout the United States.

B.2. What did you accomplish under these goals?

Specific Aim 1

A total of 528 dairy cattle fecal samples were collected across three dairy farms located in California's Central Valley and nine sampling events. Samples were analyzed for the concentration and presence of the proposed Big 5 pathogens including *Escherichia coli* O157:H7, *Salmonella*, *Campylobacter jejuni* & *coli*, *Listeria monocytogenes,* and *Cryptosporidium parvum*. All fecal samples were processed upon receipt to the lab, within 24 hours of collection with a mean time of 15 hrs, post collection. Samples were processed to quantify the microbial concentration of five zoonotic enteric pathogens commonly found in dairy cow feces. Each bacterial pathogen was quantified using a primary enrichment step in a selective medium, followed by direct extraction to quantitative polymerase chain reaction (qPCR). *Campylobacter jejuni* was grown in SAEM (semisolid agar enrichment media) while *Listeria monocytogenes*, E. coli O157:H7 and *Salmonella* spp. were grown in SEL broth. *Cryptosporidium* was quantified using microscopy. One sample from every sub stratum was randomly selected for quantification of generic E. coli using serial dilutions and direct plating methods. Microbial and molecular controls were run in tandem with sample processing. Standard curves were performed with each qPCR run. Samples with a high CT-value were rerun to eliminate potential false positive or false negative samples. Concentrations of each bacterial pathogen were estimated using an MPN calculator instead of quantifying based on gene copy numbers determined by qPCR, due to the initial enrichment process. We also performed microbial community metagenomic sequencing on a subset of samples. The data generated from these fecal samples were used to estimate risk of exposure profiles across the dairy, the risk of exposure to X gm dairy cow feces given the feces harbors one or more pathogens, stratified by production groups (calf, heifer, dry, lactating, and other) and further stratified by production subgroups (calf: pre vs. post weaned, heifer: pre vs. post 1st pregnancy, dry: far-off vs. close-up to delivering calf, lactation: high vs. low milk production, and other: hospital cows vs. cull).

Specific Aim 2

We developed and optimized methods to collect behavioral data using custom data collection templates designed using HanDBase software. Short surveys were also developed to capture occupational task demographics across the enrolled participants. Templates and surveys were beta tested on n=10 dairy workers who agreed to participate in this initial process. Interoberver reliability with a kappa statistic of 0.9 was achieved giving confidence the data were collected consistently across the two occupational data collectors. We began enrolling dairy workers in June 2019, and enrolled 44 participants. During the consenting process, workers were given the worker occupation exposure survey (WOES) to capture both demographic data along with a broad overview of daily routines not captured during the observational period. English speaking participants were enrolled by one of the two data collectors, Jennifer A. Chase or Krishna Balasubramaniam. Two translators were temporarily employed during the initial recruitment phase, then utilized as needed. Enrollment remained open for the duration of the project to account for potential attrition and/or lack of access to enrolled individuals. Each participant was assigned a unique identification number in order to provide anonymity. Following enrollment, one worker within each major job task was randomly selected to participate in the study per site visit. After finalizing the behavioral data collection methodologies, we visited the participating farms once per month from June to December 2019, unless access was not permitted. This increase in data collection frequency allowed us to gather additional data and account for delays initiating aim 2 of the project; behavioral data collection had delays associated with IRB approvals and farm recruitment. Data collection ceased due to the pandemic after December 2019.

Data collected was analyzed and used to develop risk profiles across the dairy. We collected and used nearly 1,600 observed occupation tasks over roughly 64 hours and 24 dairy worker occupation tasks to estimate risk profiles across the dairy. To differentiate the risk, we also investigated fecal-oral transmission potential by observing twelve risky-protective occupational behaviors with direct transmission potential

(touch face, touch mouth, visible fecal splash, eat/drink), indirect transmission potential (touch dairy surface, touch cow, tail whip, spray hose, use phone), and low transmission potential (wash hands, change PPE, use tractor). These results can help promote more awareness and potentially focused safety trainings in the areas of the dairy with elevated risk profiles.

Specific Aim 3
The risk profiles developed from Specific Aims 1 & 2 together highlight areas or occupational tasks that pose elevated risks. These profiles can be used as a guide to develop safety trainings and awareness to workers within that dairy sector. Preliminary findings were made publicly available on YouTube https://youtu.be/rCWv9VIUzYA and disseminated during the 2022 WCAHS seminar series.

B.3. Competitive Revisions/Administrative Supplements
Year 6 – additional year of funding through NIOSH. See B2 for accomplishments associated with Year 6 activities.

B.4. What opportunities for training and professional development did the project provide?

Under the supervision of Dr. Atwill, Ms. Chase, who is Dr. Atwill's laboratory supervisor and a Ph.D. student enrolled in the UC Davis Graduate Group of Epidemiology, developed graduate course material and led a two-hour class discussion regarding risk factors associated with the occupational exposure to zoonotic pathogens in the dairy farm environment. This exercise formed the basis of a class assignment in the course, Epidemiological Study Design, in which the graduate and MPH students used this example to develop a cohort study on occupational risk factors to pathogen exposure among livestock farmworkers.

B.5. How did you disseminate the results to communities of interest?
In May 2022, Dr. Atwill and Jennifer Chase presented a talk titled "Occupational Patterns of Acute Exposure to Zoonotic Pathogens Among California Dairy Farmworkers" at the WCAHS' Monthly Seminar Series. In addition, in June 2018, Dr. Atwill presented a talk titled "Modeling the Expected Benefits of Preventative Interventions to Reduce Dairy Worker Infection from Bovine *Cryptosporidium parvum*" at the Monthly Seminar Series. The Monthly Seminar Series hosted by the WCAHS is free and open to the public, allowing research results to be shared with a broader audience. Publications are still in preparation to further communicate the results of this research.

B.6 - What do you plan to do during the next reporting period to accomplish the goals?
N.A.

C. PRODUCTS

C.1. Publications, conference papers, and presentations

Atwill, ER. *Modeling the Expected Benefits of Preventive Interventions to Reduce Dairy Worker Infection from Bovine Cryptosporidium Parvum.* June 4, 2018. WCAHS' Monthly Seminar Series.

Chase, JA. *Agricultural exposures and the risk of enteric illness*. UCD Epi 206 Seminar, guest lecture. February 7, 2019.

Chase, JA. Occupational exposure to fecal zoonoses among California dairy workers. UCD Epi 206 Seminar, guest lecture. January 28, 2020.

Atwill, ER & JA Chase. *Occupational patterns of acute exposure to zoonotic pathogens occurring among California dairy farm workers*. WCAHS Seminar Series (online). May 2, 2022.

C.2. Website(s) or other Internet site(s) – include URL(s)

May 2022: Occupational patterns of acute exposure to zoonotic pathogens among CA dairy farm workers **https://youtu.be/rCWv9VlUzYA**

C.3. Technologies or techniques
N.A.

C.4. Inventions, patent applications, and/or licenses
N.A.

C.5. Other products and resource sharing
N.A.

D. PARTICIPANTS

D.1. What individuals have worked on the project? Please include calendar, academic, and summer months.

Commons ID	S/K	Name	Degrees(s)	Role	Cal	Aca	Sum	Foreign	Country	SS
		Andrews, Teresa		Community Education Specialist	1.91					
		Atwill, Edward R.		Professor	1.29					
		Chase, Jennifer A.		Lab Research Supervisor 1	28.08					
		Chase, Jennifer A.		LAB RSCH SUPV 1	12.48					
		Chase, Jennifer A.		LAB AST 4 SUPV	0.18					
		Krishna Natarajan, Balasubramaniam		Asst. Project Scientist	5.57					
		Krishna Natarajan, Balasubramaniam		SRA 3	0.99					
		Krishna Natarajan, Balasubramaniam		POSTDOC - EMPLOYEE	4.55					

		Li, Xunde		Associate Researcher	1.63					
		Li, Xunde		Researcher	0.24					
		Nguyen, Tran H		Lab Assistant 3	1.25					
		Wei, Ziaohong		LAB AST 3	3.17					

D.2 Personnel updates
N.A.

E. IMPACT

E.1 - What is the impact on the development of human resources, if applicable?
N.A.

E.2 - What is the impact the Public Health Relevance and Impact? The investigator should address how the findings of the project relate beyond the immediate study to improved practices, prevention or intervention techniques, legislation, policy, or use of technology in public health.

These study findings have the potential to impact public health beyond the observed study population, by promoting zoonotic disease prevention among our large population of California dairy farm workers and potential downstream transmission to their social networks (family/friends). In addition to the knowledge gained, training materials developed for zoonotic disease risk reduction will be readily applicable to farmworkers on dairies located not just in California, but also throughout the United States. Each of our Specific Aims are designed to generate one or more outputs that can be used to enhance the impact of this project through workshops, materials for worker and employer training programs, and written/online media in Spanish and English. Specifically, results from Specific Aims 1 and 2 will be used to develop training materials that characterize the relative risks of dairy cattle zoonoses and data-driven recommendations for specific preventative interventions (workplace controls, PPE, protective behavior, etc.) to mitigate these zoonotic hazards. Our results will be widely disseminated through UCCE, CDQAP, CDFA, and WCAHS across three western states (CA, NV, AZ) to encourage widespread awareness of zoonotic hazards and widespread adoption of on-farm control practices to reduce or eliminate exposure to enteric zoonotic pathogens.

F. CHANGES

F.1 – Changes in approach and reasons for change, including changes that have a significant impact on expenditures
N.A.

F.2 - Actual or anticipated challenges or delays and actions or plans to resolve them
N.A.

F.3 - Significant changes to human subjects, vertebrate animals, biohazards, and/or select agents
N.A.

G. Special Reporting Requirements

G.1 Special Notice of Award Terms and Funding Opportunities Announcement Reporting Requirements
N.A.

G.2 Responsible Conduct of Research
N.A.

G.3 Mentor's Research Report or Sponsor Comments
N.A.

G.4 Human Subjects
G.4.a Does the project involve human subjects?
Yes

G.4.b Inclusion Enrollment Data
N.A.

G.4.c ClinicalTrials.gov
N.A.

Does this project include one or more applicable clinical trials that must be registered in ClinicalTrials.gov under FDAAA?
N.A.

G.5 Human Subject Education Requirement
Are there personnel on this project who are newly involved in the design or conduct of human subject's research?
No

G.6 Human Embryonic Stem Cells (HESCS)
Does this project involve human embryonic stem cells (only hESC lines listed as approved in the NIH Registry may be used in NIH funded research)?
No

G.7 Vertebrate Animals
Does this project involve vertebrate animals?
No

G.8 Project/Performance Sites
N.A.

G.9 Foreign Component
N.A.

G.10 Estimated Unobligated Balance
G.10.a Is it anticipated that an estimated unobligated balance (including prior year carryover) will be greater than 25% of the current year's total approved budget?
N.A.

G.11 Program Income
Is program income anticipated during the next budget period?
N.A.

G.12 F&A Costs
Is there a change in performance sites that will affect F&A costs?
N.A.

I. OUTCOMES

I. Provide a concise summary of the outcomes or findings of the award, written for the general public in clear and comprehensible language, without including any proprietary, confidential information or trade secrets

Note: project outcome information will be made public in NIH RePORTER

At the group-level, we identified dairy cows that present an increased risk of exposure to zoonotic pathogens (microorganism such as bacteria, viruses, or parasites that can cause infection or disease in both humans and animals typically transferred via the fecal-oral route) by collecting fecal samples from 528 individual dairy cows. Production stage (calf, heifer, dry, lactating, and other) was used to group the cows with-in the dairy, and the cows were housed across three participating dairies in California's San Joaquin Valley. To estimate risk of exposure with more granularity, production stage was stratified into two natural substages (calf: pre vs. post weaned, heifer: pre vs. post 1st pregnancy, dry: far-off vs. close-up to delivering calf, lactation: high vs. low milk production, and other: hospital cows vs. cull). These risk indices were pared with nearly 1,600 observed occupation tasks over roughly 64 hours and 24 dairy worker occupation tasks to estimate risk profiles across the dairy. To differentiate the risk, we also investigated fecal-oral transmission potential by observing twelve risky-protective occupational behaviors with direct transmission potential (touch face, touch mouth, visible fecal splash, eat/drink), indirect transmission potential (touch dairy surface, touch cow, tail whip, spray hose, use phone), and low transmission potential (wash hands, change PPE, use tractor). These results can help promote more awareness and potentially focused safety trainings in the areas of the dairy with elevated risk profiles.