Life Elevated in the Intermountain West Through STEPPES (Standardization of Training, Evaluation, Partnerships, Prevention, Efficacy, and Surveillance)

Project Narrative

a. Background

Mosquitoes and ticks are the two most important taxon of arthropods affecting human health in the United States, with the vector-borne pathogens transmitted by them causing significant annual morbidity and mortality and further exacerbating an already overburdened public health infrastructure (Gubler 1998, Bear et al. 2019). Moreover, these two taxa contain the most prolific invasive species globally, further introducing exotic pathogens in new areas with naïve host populations (Lounibos 2002, Eisen et al. 2016, Hahn et al. 2017, Rochlin et al. 2023). As a result, vector-borne diseases continue to grow in the United States, showing an increase of 100% over the last two decades alone (CDC 2020). The leading tick-borne illness is Lyme disease, with an approximate 30,000 reported cases annually, while the mosquito-borne West Nile virus (WNV) has been responsible for nearly 55,000 cases between 1999-2019 (CDC 2021). However, because many patients may not seek medical assistance and overall underreporting of cases, the values above may be grossly underestimated and more realistic numbers may exceed 300,000 annual cases for Lyme disease and nearly 7 million WNV infections during 1999-2019 (Beard et al. 2019, Ronca et al. 2021). Nonetheless, Lyme disease and WNV are only the tip of the iceberg, and many other endemic and exotic vector-borne pathogens are routinely detected in the United States. These include the endemic vector-borne diseases of anaplasmosis/ehrlichiosis, babesiosis, Colorado tick fever, eastern equine encephalitis, La Crosse and Powassan viruses, spotted fever rickettsiosis, St. Louis encephalitis, western equine encephalitis, and the exotic pathogens responsible for chikungunya, dengue, Japanese encephalitis, Rift Valley fever, and Zika virus infections. In the state of Utah, although WNV is the most significant vector-borne disease impacting human health, sporadic cases of St. Louis encephalitis, western equine encephalitis, Colorado tick fever, Rocky Mountain spotted fever, and even Zika virus have been detected in the past. In fact, Utah was at the forefront of the Zika virus pandemic in the United States during 2016, with the reported death of a 73-year-old male in a Salt Lake City hospital after travel from Mexico, and the subsequent person-to-person transmission with a 38-year-old male family contact (Krow-Lucal 2017). Due to the widespread and increasing distributions of

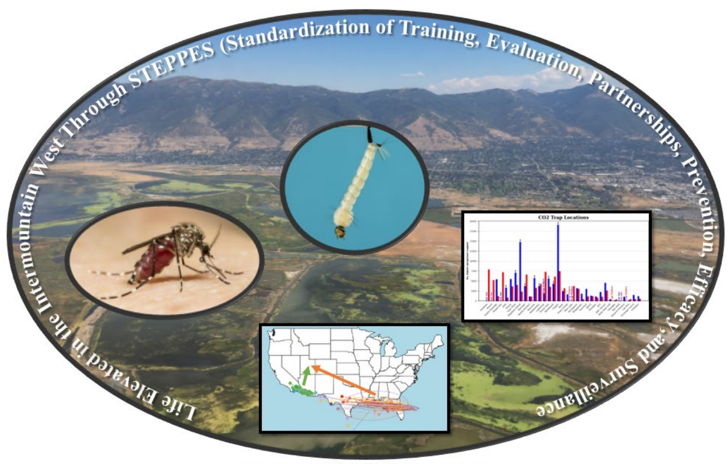

Figure 1. Life elevated in the Intermountain West through STEPPES (standardization of training, evaluation, partnerships, prevention, efficacy, and surveillance).

vectors in temperate regions of North America and the escalating diagnoses of cases in travelers returning from endemic or epidemic areas with a higher rapidity and frequency, the risk of local transmission of exotic pathogens is no longer conjectural. Given the unique climatology, topography, ecology, human population growth, intensifying land use pattern changes, and incomparable missionary culture of the general population where more than 68% of Utahns are reported as members of The Church of Jesus Christ of Latter-day Saints (World Population Review 2023), it is more imperative than ever to build the vector-borne disease prevention and control workforce and facilitate partnerships between academia, vector control personnel, and health agencies in the state of Utah for the betterment of public health stewardship for all. Hence, **we propose the creation of "Life Elevated in the Intermountain West Through STEPPES (Standardization of Training, Evaluation, Partnerships, Prevention, Efficacy, and Surveillance)"** (Figure 1).

Fortunately, Utah has long benefitted from an intricate network of mosquito abatement districts (MADs) and a remarkable relationship with public health departments at the State, county, and local level. This network has been tested time and time again, with the most recent example in the detection of the invasive yellow fever mosquito, *Aedes aegypti*, in the isolated southeastern city of Moab (Gloria-Soria et al. 2022). This species was detected on 29 August 2019 by the Moab MAD; however, because of the lack of resources (pesticides, control and surveillance equipment, funding), familiarity with a container-inhabiting and diurnal species, and man-power, the Moab MAD requested the assistance of other MADs in the state. Five MADs responded, led by the Salt Lake City MAD, and mounted aggressive educational, surveillance, and control campaigns utilizing newly established Best Management Practices, Train-the-Trainer Workshops, and E-Modules, which were sponsored by the CDC and developed by the American Mosquito Control Association (Faraji and Unlu 2016; AMCA 2017a,b). These efforts led to the extermination of *Ae. aegypti* in 2019 and lack of detection during 2020, as well. Incidentally, the source of introduction during 2019 in Moab, Utah, was shown to be monophyletic and most likely stemming from Tucson, Arizona, where large populations of *Ae. aegypti* thrive (Gloria-Soria et al. 2022). Furthermore, the close kinship estimates using small nucleotide polymorphisms suggest over 53% of the pairwise relationships of the samples analyzed were first degree parent/progeny or full siblings, suggesting that the initial introduction may have been by a single adult female via vehicle-assisted transportation and not the traditional route of desiccation-resistant egg transport in artificial containers (Gloria-Soria et al. 2022). This finding further highlights the need for close monitoring of tourist hotspots and/or border towns for invasive species. Furthermore, despite complete elimination of the species in 2019 and 2020, *Ae. aegypti* was once again detected in small numbers in Moab during 2021 and exploded in abundance in that town during 2022 (Moab MAD personal communication). Moab MAD is currently understaffed, underfunded, and unequipped to combat an invasive mosquito species, and this situation will be further drastically intensified with the introduction of an exotic pathogen that could be vectored by *Ae. aegypti*.

Moab MAD is not alone in its struggles with funding, staffing, equipment, and vector control products within our region. Although Utah has a rich history of mosquito control, having passed legislation for the creation of the Salt Lake City MAD in 1923 and only being surpassed by New Jersey in 1912 and California in 1915 (Patterson 2009), a lot of variation exists in the MAD programs throughout the State. There are currently 24 established MADs in Utah; however, they range from independent taxing districts to small dependent programs housed within cities, counties, or departments of health or public works (UMAA 2023). The budgets of the larger districts may approach $10 million USD with over a dozen full time employees and 35 seasonal employees, while the smaller programs may operate with a budget of $11,000 and a single seasonal employee. This disparity is further highlighted in rural areas that may have lower income and members of minority communities such as the Shivwits Band of Paiutes, Utah Navajo Health System, Ute Indian Tribe Mosquito Abatement Department, and other isolated remote programs. These remote communities may experience greater quality of life impact and higher rates of vector-borne disease; however, because of lack of resources available for surveillance and control, it has been difficult to gauge these burdens. Unfortunately, this scenario is all too common throughout Utah and the United States. In fact, during 2017, a survey conducted on mosquito control capabilities in the United States by the National Association of County and City Health Officials reported that an overwhelming majority of vector control programs (84%) are in need of improvement (NACCHO 2017). A follow up survey in 2020 only showed a slight enhancement within vector control programs, with 72% of the respondents still falling within the "needs improvement" category (NACCHO 2020). Additionally, although only 31% of respondents reported capacity to conduct pesticide resistance testing, it was shocking to realize that another 32% of the programs do not possess core capabilities to conduct routine mosquito surveillance, standardized trapping, or species identification; and another 34% were not capable to cooperate with other partner vector control programs (NACCHO 2020). If a vector control program cannot conduct routine and standardized surveillance of vector species, abundance, and pathogen infection rates, then they cannot possibly evaluate the efficacy of their intervention efforts on target pest populations.

Our primary aim with Intermountain STEPPES is to fix these gaps and disparities throughout the state of Utah through building and enhancing capacities, standardizing application, surveillance, and evaluation methods, training the next generation of public health specialists, and partnering those programs in need with collaborative activities between students at local colleges and universities. Our Intermountain STEPPES program is specifically designed to increase the interactions and collaborations with students in academic institutions and MADs in a truly win-win situation. The students will assist the MADs during the active mosquito season, obtain a real-world applied experience, and be holistically trained in the field of vector surveillance and control. They will be exposed to various integrated vector management techniques, pesticide safety, active ingredient mode of action, pesticide selection, calibration of vector control equipment, determination of application rates, personal protection equipment, bioassays for determination of efficacy, insecticide resistance monitoring, vector biology/ecology, field epidemiology, vector surveillance techniques, vector identification, habitat recognition, species bionomics, Before-After Control-Impact evaluation, pathogen testing, data entry for statewide dissemination of surveillance data using VectorSurv, arthropod husbandry, and public outreach, amongst many other activities. At the same time, the students will assist the local MADs throughout the State in various evaluation determinations of existing vector control methods. This latter service is particularly important because many of the MADs simply do not have the manpower, equipment, or time to conduct efficacy evaluations of their vector control intervention methods after each application. Many also lack the computer skills necessary to input data in a state-wide repository. The placement of students within MADs will increase the accountability and capabilities of all the districts throughout the state of Utah. Additionally, we also aim to provide additional training for all vector control technicians, public health personnel, university/college students, private pest control operators, and other partners through a series of workshops and train-the-trainer events on an annual basis. These trainings will range from vector biology, epidemiology, pesticide and human health risk assessment, pesticide science, vector identification, insecticide resistance monitoring, arbovirus diagnostic fidelity, public outreach and communication, and health education messaging, amongst others. We have established a phenomenal network of partners through our Intermountain STEPPES program, ranging from 13 academic institutions and departments within Utah and three universities from out of state; 11 MADs; three Native American tribal partners; five regional county health departments; two state health departments (DHSS and UPHL); a state public health association (UPHA); two state department of agriculture partners (State Entomologist and State Veterinarian); four private industry partners; a state prison (Department of Corrections); a science education outreach program (Science Moab); a local branch of a national non-profit environmental organization (Audubon Gillmor Sanctuary); and a federal partner (USDA-ARS). This interdisciplinary group of partners has been strategically selected to enhance the capabilities of public health stewardship in the state of Utah. With the incessant pressures from vectors and vector-borne diseases, growing human populations, drastic changes in land use patterns, increasing insecticide resistance burdens, global climate change enhancing the movement and rate of reproduction of vectors and the pathogens that they harbor, and the frequency and rapidity of human global travel and invasive species, it is more imperative than ever to build partnerships and increase the training and capabilities of the next generation of the public health workforce to ensure a future where enhancement of quality of life and public health protection from vector-borne diseases is not a privilege for the wealthy few, but an expectation for all. This is a vision that is certainly achievable through the Intermountain STEPPES program in the state of Utah, and can serve as an exemplary model that could be leveraged in other locations.

b. Approach

i. Purpose

Our application for the creation of "Life Elevated in the Intermountain West Through STEPPES (Standardization of Training, Evaluation, Partnerships, Prevention, Efficacy, and Surveillance)" in the State of Utah flawlessly interlaces the mosquito and vector control community with public health personnel at departments of health and Native American tribal councils, while incorporating academic institutions and the plethora of students who are eager to gain valuable field experience as future stewards of public health. Our Intermountain STEPPES program has incorporated an intensive training curriculum for students (undergraduate and graduate) and practicing vector control professionals, and will partner these students with vector control districts to leverage the evaluation of intervention efforts in real-world settings. We have assembled an additional unique set of partners, ranging from private industry to a non-profit environmental group, and a federal partner, to address the existing gaps in vector surveillance and control in our region. Our district, and our partners, are perfectly positioned to address the specific asks in the notice of funding opportunity and reach rural, remote, lower income, underserved, and minority populations that may be disproportionately at a higher risk for arbovirus transmission (Native American Tribes, incarcerated and unhoused populations). Our communication and outreach experts will also improve understanding of risk, prevention, and control of vector-borne diseases and assist with improved messaging for the general public. The partnerships through Intermountain STEPPES will undoubtedly lead towards improvements in the public health infrastructure within our region and an informed workforce which will proactively be prepared to handle any public health emergency.

ii. Outcomes:

Training:

The Intermountain STEPPES program aims to provide training for students and public health professionals (vector control personnel, health officers, epidemiologists, pest control operators, private industry partners) through two major mechanisms. **First, the Salt Lake City MAD will host a week-long workshop at their facility where all partners and students will be invited to attend and participate.** The workshop will be a combination of lectures, presentations, case studies, hands-on equipment training, vector identification, and field/semi-field sampling. These lectures and workshops will be led by various team members from the MADs to the health departments and academia and will include topics such as integrated vector management techniques, best management practices, pesticide safety, active ingredient mode of action, pesticide selection, calibration of vector control equipment, determination of application rates, personal protection equipment, bioassays for determination of efficacy, insecticide resistance monitoring, vector (mosquito and tick) biology/ecology, field epidemiology, arbovirology, disease ecology, vector (mosquito and tick) surveillance techniques, vector (mosquito and tick) identification, habitat recognition, species bionomics, Before-After Control-Impact evaluation, good laboratory practices, molecular techniques, pathogen testing, data entry for statewide dissemination of surveillance data using VectorSurv, arthropod husbandry, and public outreach, amongst many other activities. In addition to our academic partners and public health specialists who already hold expertise in providing this type of training, two of the PI's from Salt Lake City MAD have been certified as Master Trainers and have led similar workshops and Train-the-Trainer events around the United States on best management practices for invasive *Aedes* surveillance and control. Our annual training will mimic those workshops and provide an *active* training for attendees where real-world scenarios and case studies will be presented. Additionally, the Salt Lake City MAD already has experience in leading a training workshop for the Utah Mosquito Abatement Association for all mosquito abatement employees (200) in Utah at their facility each year. A large benefit of this workshop will be the capability of providing financial assistance for members of the vector-borne disease prevention and control workforce in rural areas and minority communities, such as the Native American Tribal programs, for attendance and participation. Additional information on this training workshop and involvement of our partners may be found in the additional documents and letters of support. Last, our ultimate goal with the workshop is to parlay this training into an official certificate program and/or undergraduate/graduate course which would be jointly offered by the University of Utah (UU) and Utah State University (USU) in years 4-5 of the grant. This course would provide weekly lectures and laboratory experiences for attendees over the course of an entire spring semester, covering the topics mentioned above. The course would also include a field component where students would be taken into the field and trained on habitat recognition, larval/adult sampling of vectors; coupled with insect rearing, laboratory identification, testing, etc. Our partners at UU/USU are currently in discussions for determining the most appropriate mechanism to make this a reality. In particular, USU, which is one of the nation's premier student-centered land grant universities, has satellite offices in remote locations with the Intermountain region and a precedence already exists for collaborative certification programs on other topics jointly offered by UU/USU. This course would be offered to professionals as continuing education credits and a certificate upon completion, and available to undergraduate and graduate students with different course and expectation requirements.

The second component of the Intermountain STEPPES training program aims to place students directly into the field as interns and summer employees at various MADs, health departments, and Native American Tribal programs. Many of the smaller vector control operations in the state do not have the resources, equipment, or personnel in order to conduct evaluations of abatement measures. This partnership will strategically place students from nearby colleges/universities within vector control units to assist with evaluations, while also providing enormous field experience for the students to complement their academic experiences and allow them to become well-rounded public health specialists of the future. It is imperative for the next generation of public health stewards to not only understand disease epidemiology, but also acquire hands-on experience with field surveillance, pesticide science and safety, and effective intervention methods. In addition to gaining field experience with various aspects of vector surveillance and control, the students will also gain valuable practice with interacting with the public and various user groups and understanding effective communication strategies, a skill that they will undoubtedly need in their future endeavors. It is important to note that we will not only target university students, but also community college students. In particular, one of our partners, Salt Lake Community College (SLCC), is the most diverse institution in the State of Utah. The Intermountain STEPPES collaboration with SLCC will provide an opportunity to train the next generation of underrepresented students in STEM, which is even more important as SLCC is officially being designated as a Hispanic Serving Institution in the near future. It is also important to note that the Salt Lake City MAD is well-experienced in the utilization of students, interns, and visiting technicians every year. The District has built a stand-alone dormitory, where students, interns, technicians, private industry partners, and visiting scientists, may utilize during their visits. The dormitory is also directly attached to a laboratory, where students/interns may conduct their own evaluation schemes and bioassays around the clock. Additionally, Salt Lake City MAD has an existing memorandum of understanding with two local high schools for placement of high school interns every active mosquito season in the district. Additionally, Salt Lake City MAD acquires 5-10 college interns from across the United States every summer, and has even provided field experience for other vector control technicians from other states and as far away as Costa Rica, Ghana, Kenya, and Mali. Furthermore, the District has recently also created two memorandums of understandings with the University of Utah for field/laboratory applied training of students through the Science Research Initiative (SRI) and the Community Engaged Learning (CEL) program. Both of these programs have placed undergraduate students within our District during the academic and active mosquito season. Last, Salt Lake City MAD has recently been selected as one of the few recipients of the Entomological Society of America's (ESA) Public Health Entomology for All (PHEFA) program. This initiative is a partnership between the Centers for Disease Control and Prevention's Division of Vector-Borne Diseases (CDC-DVBD) and ESA. The PHEFA program was created to help address the lack of diversity in the field of entomology by providing valuable opportunities for minorities and underserved populations to gain experience and exposure in the field of public health and applied sciences. A diverse workforce strengthens the field's ability to develop successful, community-accepted prevention and intervention efforts. It is critical for the public health workforce to reflect the communities they serve, and PHEFA is implementing strategies that expand the racial, cultural, demographic, and experiential diversity of the public health entomology workforce. By building a more diverse workforce, the field will be better prepared to identify health disparities and ensure health equity. The Salt Lake City MAD is proud to be one of the first partners with ESA and CDC-DVBD and we hope to leverage this partnership into the Intermountain STEPPES training program and provide opportunities for other MADs to participate in this program from our region. For additional information on the various programs mentioned above, please refer to the additional documents and letters of support.

The Intermountain STEPPES training program will benefit from the above two training mechanism, with direct measurable outcomes in the short-, intermediate, and long-term basis. In the short-term basis, the workshop will increase the awareness and knowledge base of all students and public health specialists in the various topics mentioned above. Attendees will be informed about vectors and vector-borne pathogens, vector identification, habitat recognition, pesticides science and applications, best management practices, effective surveillance techniques, good laboratory practices, insecticide resistance monitoring, pathogen testing, etc. The immediate outcome of this training, in addition to increasing professionalism, will be the standardization of various methods in the entire region to increase consistency and accountability. We hope to increase the capacity of underserved communities by eventual placement of students as public health officers, epidemiologists, and vector control technicians within these communities. A well-trained workforce will also be more vigilant and better informed to respond to a public health emergency. In addition to the traditional students in the fields of entomology, biology, public and environmental health, one of our partners is also actively accessing medical students at the local universities. The training of future health practitioners, particularly in regards to pesticide safety and diagnostic fidelity, will be an intermediate and long-term outcome that will increase the knowledge and responsiveness for the benefit of public health. An additional intermediate and long-term outcome is the training of students and professionals in outreach communication to better transfer information to the public and other entities. The subsequent training will also lead to improved ability of professionals to determine risk and implement effective best management strategies for vectors and disease suppression. Our long-term goal of developing a continuing education certification program for professionals and a undergraduate/graduate course for students at the university would lead to a competently trained workforce that would eventually lead public health and vector control programs and reduce the morbidity and mortality rates associated with vector-borne pathogens.

Evaluation:

The Intermountain STEPPES program aims to provide evaluation of vector control methods in existing and developing programs through two major field investigations. **First, the efficacy of a long-lasting granular larvicide formulation of an insect growth regulator (Sumilarv WSP, active ingredient pyriproxyfen) will be evaluated in peridomestic catch basin habitats to target the primary enzootic vector of WNV, *Culex pipiens*, in Utah.** Many vector control programs in the United States conduct routine applications of mosquito larvicides in residential catch basins and curb side gutters to control juvenile populations of mosquitoes. These habitats are particularly conducive to producing *Cx. pipiens* complex mosquitoes, which serve as a main enzootic vector of WNV (Farajollahi et al. 2011). Because of the ubiquity and large amount of these larval developmental sites within peridomestic habitats, most vector control programs do not have the manpower or resources to conduct efficacy evaluations of these applications. Many programs simply conduct a larvicide application in a catch basin and quickly move on to the next mosquito source. In Salt Lake County alone, there over 72,000 catch basins.

Furthermore, most of the commonly used larvicide products in these sources only claim a 30-day efficacy period. Hence, three to four applications may be needed in the same catch basin over the course of the mosquito season, which is a large use of man power and a big percentage of pesticide budgets for many vector control programs. Additionally, *Cx. pipiens* mosquitoes from Salt Lake City have shown resistance to the active ingredient, *Bacillus sphearicus*, which is the most commonly used product in catch basins (Su et al. 2019). We propose to use a newly available insect growth regulator larvicide (Sumilarv WSP), which has been shown to have at least a 160-day efficacy period in catch basins against mosquitoes in California (Elkashef et al. 2019). We will evaluate the efficacy of this product over the entire mosquito control season and will conduct investigations in three separate geographic areas (North, Central, and Southern Utah) within 13 operational programs. Academic partners will assist the vector control programs with much needed field work through placement of students at each district to assist with field sampling, monitoring, bioassays, identification, insecticide resistance monitoring, etc. as needed. This will provide valuable field training for the students and help MADs determine if this product will be effective in helping control larvae throughout the duration of the mosquito season and lead to decreased cases of WNV within the regions.

The second component of the Intermountain STEPPES evaluation program will concentrate on the efficacy of adult control products (adulticides) against mosquito vectors of disease in Utah. These evaluations will be further divided into three components, consisting of wind tunnel evaluations (to determine overall efficacy and effective application rates prior to field usage); ground-based ultra-low volume (ULV) truck-mounted adulticide evaluations; and fixed-wing ULV aerial evaluations. Due to the absence of effective vaccines for many mosquito-borne pathogens, the reduction of biting adult populations of the primary vectors is the only effective means of reducing disease cases during an epidemic. Most federal and state guidelines for protecting the public during disease outbreaks recommend adulticides from truck-mounted equipment and aircraft as the most effective method of reducing transmission risk to humans (CDC 2013). These adulticide interventions are generally applied as ULV cold aerosol sprays during night-time campaigns when a thermal inversion has occurred to keep the insecticide from dispersing upwards and light winds aid in the spread of the insecticide droplets (Mount 1998). For mosquito adulticide spraying, a droplet size range of 5 to 25 µm is most efficient, because this size is most likely to impinge on a mosquito and deliver a toxic dose (Haile et al. 1992). Droplet measurements for mosquito control are often provided as a mass median diameter or a volume median diameter (VMD). The VMD is also routinely provided as $DV_{0.5}$, a term used to represent a statistic where 50% of the spray volume or mass is contained in droplets smaller than this value (Farajollahi et al. 2012). Most often, values for a $DV_{0.1}$ and a $DV_{0.9}$ are also provided, to describe 10% and 90% of the cloud volume, respectively. Droplet size and distribution are two of the most important factors affecting the success of an ULV application (Farajollahi et al. 2012). Additionally, adulticide labels, which are interpreted as federal law, require that given equipment adhere explicitly to required VMD values. Because many vector control programs do not have the capabilities and resources for conducting calibration of equipment, the Salt Lake City MAD will partner with private industry and provide this service for all prior to the start of the active mosquito season. This will be assisted by student interns in the field. Additionally, the wind tunnel evaluations will determine the efficacy of an adulticide product (essentially insecticide resistance monitoring which will also be complemented through traditional CDC bottle bioassays) and the most effective application rate to be utilized in the field. Furthermore, because of topography, vector abundance, and operational capabilities of vector control programs, the evaluation of adulticide efficacy in the field will either be determined via truck-mounted or aerial equipment. However, regardless of method used, vector abundance, species composition, pathogen infection rates, and parity status of mosquitoes will be determined in the field before and after each application. This evaluation scheme will be conducted primarily through the workforce of student interns that will be assisting the MADs. Additionally, all data will be tabulated by the students and input into VectorSurv, a web-based platform for data management and analysis that is used by vector control and public health agencies in the United States. This program was developed in UC Davis and initially utilized only in the State of California. However, the Salt Lake City MAD was the first vector control program to utilize this platform outside of California in partnership with UC Davis and make it available to other MADs in Utah. Unfortunately, because of the lack of man-power and technical capabilities, only about eight MADs currently use the software. Another objective of this proposal is to train the student interns to assist the MADs and public health departments with data entry into VectorSurv (current and historic data) to expedite relevant mosquito and pathogen information. Incidentally, VectorSurv is now being utilized in 15 states and five United States Affiliated Pacific Islands (C. Barker personal communication). Furthermore, in order to determine the efficacy of adulticide applications in reducing the infected and parous portion of mosquito populations, intensive pathogen infection testing and parity dissections will be conducted. Many of the MAD's have the capabilities of conducting in-house pathogen testing; however, for those that do not, we will assist them in acquiring the necessary equipment and providing the needed training so that they can continue to do this on their own independently. This component will be conducted in collaboration with private industry (Co-Diagnostics, a Utah-based publicly traded company that specializes in providing high quality molecular diagnostic solutions to the underserved and those without access to innovative and expensive molecular technology). Co-Diagnostics, in partnership with the State of Utah Public Health Laboratories will provide training to rural, lower income, and minority communities for pathogen testing, such as the Ute Indian Tribe Mosquito Abatement. Student interns, will also be trained in molecular techniques and parity dissections, and will assist the MADs each season through the training/placement program. The ultimate goal of these evaluations is an increase in vector control response rates for the protection of public health in all communities.

The Intermountain STEPPES evaluation program will benefit from the above two efficacy schemes with direct measurable outcomes in the short-, intermediate, and long-term basis. In the short-term basis, the evaluations of larvicides and adulticides through a carefully detailed and concerted effort will increase the capacity and capabilities of the vector control programs. Some of these programs may not currently conduct any larvicide catch basin applications for enzootic vectors of WNV, hence the incorporation of a new program will tremendously benefit the local community by reducing disease burden. The same concept applies to insecticide monitoring, which may be nonexistent in many of the MADs, particularly in rural areas where resources, funding, manpower, and expertise are major obstacles. Additionally, many of the MADs throughout the state currently do not conduct any before-after-control impact evaluations. They simply do not possess the equipment, the time, or manpower to conduct these evaluations with each application. Our rigorous efforts, in partnership with placement of students in each MAD, will finally allow a consistent determination of percent reduction following ULV adulticide applications. This is particularly important, as adulticiding is the most controversial component of any vector control program and should be justified for need to appease public and environmental group concerns. Student interns will assist with trapping, identification, percent reduction in mosquito abundance, species composition impact, reduction of infected mosquitoes (through pathogen testing), and reduction of the parous portion of the mosquito population (through parity dissections). The immediate outcome of these evaluations, in addition to increasing accountability and professionalism, will be the standardization of various methods in the entire region for vector surveillance. The sustaining partnerships between MADs and university students will also lead to intermediate and long-term outcomes for improved ability of professionals to determine risk and implement effective best management strategies for vectors and disease suppression. A strengthened public health workforce ultimately leads to reduced morbidity and mortality rates associated with vector-borne pathogens and enhancement of quality of life.

iii. Strategies and Activities:

STRATEGY 1: TRAIN – Increased opportunities for students and professionals to receive training in vector-borne disease (VBD) prevention and control.

Our entire proposal and program has been built around providing real-world training for the next generation of public health stewards. This training will occur at an annual week-long workshop located at the Salt Lake City MAD; through designed coursework at academic institutions for graduate and undergraduate students; through mentorship by public health and vector control professionals and post-docs; through placement of students and interns within vector control programs; and through the eventual creation of a certificate and academic curriculum offered jointly through the University of Utah and Utah State University.

Required activities:

1. **Conduct training and educational needs assessments for VBD prevention and control professionals and students to develop and maintain readiness across the existing VBD workforce.**
   In collaboration with the University of Utah's Public Health Department, we will conduct an assessment of the baseline knowledge of prevention and control of vector-borne disease amongst students and professionals in public health, environmental health, infectious disease medicine, vector control; and evaluate the effectiveness of the training activities of this program by re-administering the knowledge assessment in the final year of the program.
   Additionally, the University of Utah's Public Health Department will conduct a formative evaluation of the knowledge, attitudes, and practices of the general public in Utah in regards to prevention and control of vector-borne diseases. This formative evaluation will provide evidence for the development of professional training activities as well as for the development of potential prevention intervention. This activity will further highlight gaps that may exist in socioeconomics between residents of more affluent eastern communities where mosquito burden is low, as compared to residents in less affluent western communities who are inundated by mosquitoes impacting quality of life and suffer from higher rates of mosquito-borne disease.

2. **Define training and education goals for VBD prevention and control programs.**
   Training of public health stewards and vector control professionals will consist of a combination of classroom, laboratory, and field experiences for trainees. A mixture of lectures, presentations, case studies, hands-on equipment training, vector identification, and field/semi-field sampling will be offered. These lectures and workshops will be led by various team members from the MADs to the health departments and academic institutions, and will include topics such as integrated vector management techniques, best management practices, pesticide safety, active ingredient mode of action, pesticide selection, calibration of vector control equipment, determination of application rates, personal protection equipment, bioassays for determination of efficacy, insecticide resistance monitoring, vector (mosquito and tick) biology/ecology, field epidemiology, arbovirology, disease ecology, vector (mosquito and tick) surveillance techniques, vector (mosquito and tick) identification, habitat recognition, species bionomics, Before-After Control-Impact evaluation, good laboratory practices, molecular techniques, pathogen testing, data entry for statewide dissemination of surveillance data using VectorSurv, arthropod husbandry, and public outreach, amongst many other activities. In addition to our academic partners and public health specialists who already hold expertise in mentorship and providing this type of training, two of the PI's from Salt Lake City MAD have been certified as Master Trainers and have led similar workshops and Train-the-Trainer events around the United States on best management practices for invasive Aedes *surveillance and control. Our annual training will mimic those workshops and provide an active training for attendees where real-world scenarios and case studies will be presented. A large benefit of this workshop will be the capability of providing financial assistance for members of the vector-borne disease prevention and control workforce in rural areas and minority communities, such as the Native American Tribal programs, for attendance and participation. The overall goal is to develop a well-informed student and professional staff who are competent and capable of responding effectively to any vector-borne disease outbreak.*

3. **Train undergraduates, graduate students, or post-doctoral fellows, such as those involved in the fields of human or veterinary medicine, entomology, vector control, public health, and environmental health, to strengthen the workforce of prepared VBD prevention and control professionals.**
   Training of the next generation of public health undergraduate, graduate, or post-doc fellows will be composed of two major components. The first will consist of a combination of classroom, laboratory, and field experiences for trainees. A mixture of lectures, presentations, case studies, hands-on equipment training, vector identification, and field/semi-field sampling will be offered. These lectures and workshops will be led by various team members from the MADs to the health departments and academic institutions, and will include topics such as integrated vector management techniques, best management practices, pesticide safety, active ingredient mode of action, pesticide selection, calibration of vector control equipment, determination of application rates, personal protection equipment, bioassays for determination of efficacy, insecticide resistance monitoring, vector (mosquito and tick) biology/ecology, field epidemiology, arbovirology, disease ecology, vector (mosquito and tick) surveillance techniques, vector (mosquito and tick) identification, habitat recognition, species bionomics, Before-After

Control-Impact evaluation, good laboratory practices, molecular techniques, pathogen testing, data entry for statewide dissemination of surveillance data using VectorSurv, arthropod husbandry, and public outreach, amongst many other activities. In addition to our academic partners and public health specialists who already hold expertise in mentorship and providing this type of training, two of the PI's from Salt Lake City MAD have been certified as Master Trainers and have led similar workshops and Train-the-Trainer events around the United States on best management practices for invasive Aedes *surveillance and control. Our annual training will mimic those workshops and provide an active training for attendees where real-world scenarios and case studies will be presented. A large benefit of this workshop will be the capability of providing financial assistance for all partnering academic institutions within Utah to send interested students to the workshop. Additionally, our partners at the University of Utah's Public Health Department will develop up to five modules on vector-borne disease prevention and control to be used in a variety of educational programs (undergraduate and graduate level public health, environmental health, health education, and occupational health as well as undergraduate and graduate medical education) and for existing professionals. These modules will be available to all partnering educational institutions in Utah (and surrounding states) and/or through the existing University of Utah Public Health Learning Management System. Last, in years 4-5 of the grant, we aim to create a graduate/undergraduate academic course offered jointly through the University of Utah and Utah State University (USU). USU is a land grant institution that is devoted to providing high quality affordable educational opportunities to students who might not otherwise have access. USU's statewide program includes 8 campuses and 23 education centers across the state, with a total of 30 locations with broadcasting capabilities across the state. The network allows students in rural communities to remotely attend courses being broadcast from any USU campus. Here we propose to leverage the pre-existing infrastructure to provide opportunities for students in rural areas to collaborate with faculty and education specialists, professionals, other trainees, and vector control experts across the state without having to leave their communities and obligations at home. Although it is well documented that this type of education and technical training can provide individuals with increased access to job opportunities, networking opportunities, and earning potential, young people from rural areas remain less likely to attend university than their urban counterparts. Additionally, many rural USU campuses serve high percentages of first generation (nearly 40% of students at the Price campus are first generation), and underserved populations (USU Blanding is designated as a "Native American Serving Nontribal Institution"). While this gap in educational attainment in these groups arises from both practical and perceived barriers, if awarded, the CDC training and evaluation grant, can bring high quality training directly to the students that will benefit from it the most. We will also work with other academic institutions in the state to allow for cross attendance and credit for interested students.*

The second component of training consists of placement of students directly into the field as interns and summer employees at various MADs, health departments, and Native American Tribal programs. Many of the smaller vector control operations in the state do not have the resources, equipment, or personnel in order to conduct evaluations of abatement measures. This partnership will strategically place students from nearby *colleges/universities within vector control units to assist with evaluations, while also providing enormous field experience training for the students to complement their academic experiences and allow them to become well-rounded public health specialists. It is imperative for the next generation of public health stewards to not only understand disease epidemiology, but also acquire hands-on experience with field surveillance, pesticide science and safety, and effective intervention methods. In addition to gaining field experience with various aspects of vector surveillance and control, the students will also gain valuable practice with interacting with the public and various user groups and understanding effective communication strategies, a skill that they will undoubtedly need in their future endeavors. Additionally, one of our partners at Utah State University will provide a post-doctoral fellow, who will also act as the Training Coordinator on our proposal. This individual will not only be trained according to the above, but will also serve as a direct mentor for additional undergraduate and graduate students during the entire course of this grant. The overall goal is to develop a well-informed student body who are competently trained in all aspects of vector surveillance and control, and are capable to hit the ground running upon placement in the workforce.*

4. **Train and educate VBD prevention and control professionals, such as those involved in the fields of human or veterinary medicine, entomology, vector control, public health, and environmental health.**
Training of VBD prevention and control professionals will primarily center around a week-long annual workshop administered by Salt Lake City MAD. All professionals within vector control, public health entities, pest control operators, and private industry will be encouraged to attend a combination of classroom, laboratory, and field experiences for trainees. A mixture of lectures, presentations, case studies, hands-on equipment training, vector identification, and field/semi-field sampling will be offered. These lectures and workshops will be led by various team members from the MADs to the health departments and academic institutions, and will include topics such as integrated vector management techniques, best management practices, pesticide safety, active ingredient mode of action, pesticide selection, calibration of vector control equipment, determination of application rates, personal protection equipment, bioassays for determination of efficacy, insecticide resistance monitoring, vector (mosquito and tick) biology/ecology, field epidemiology, arbovirology, disease ecology, vector (mosquito and tick) surveillance techniques, vector (mosquito and tick) identification, habitat recognition, species bionomics, Before-After Control-Impact evaluation, good laboratory practices, molecular techniques, pathogen testing, data entry for statewide dissemination of surveillance data using VectorSurv, arthropod husbandry, and public outreach, amongst many other activities. In addition to our academic partners and public health specialists who already hold expertise in mentorship and providing this type of training, two of the PI's from Salt Lake City MAD have been certified as Master Trainers and have led similar workshops and Train-the-Trainer events around the United States on best management practices for invasive Aedes *surveillance and control. Our annual training will mimic those workshops and provide an active training for attendees where real-world scenarios and case studies will be presented. A large benefit of this workshop will*

be the capability of providing financial assistance for all partnering academic institutions within Utah to send interested students to the workshop. Additionally, our partners at the University of Utah's Public Health Department will develop up to five modules on vector-borne disease prevention and control to be used in a variety of educational programs (undergraduate and graduate level public health, environmental health, health education, and occupational health as well as undergraduate and graduate medical education) and for existing professionals. These modules will be available to all partnering public health and pest control professionals. Last, in years 4-5 of the grant, we aim to create a continuing education course offered jointly through the University of Utah and Utah State University. Additionally, VBD prevention and control professionals will be working jointly with academic partners (students, post-docs, professors) in the field and will gain direct training on various components of vector surveillance and control.

5. **Develop and implement an evaluation and performance monitoring/improvement plan to evaluate the impact of training programs and ensure training goals are accomplished.**
   Annual surveys will be conducted with all trainees, students, and VBD prevention and control professionals to ensure efficacy of training and implementation. In collaboration with the University of Utah's Public Health Department, we will conduct annual assessments of the baseline knowledge of prevention and control of vector-borne disease amongst students and professionals in public health, and evaluate the effectiveness of the training activities of this program by re-administering the knowledge assessments.

6. **Conduct training at the community college level, including establishing partnerships with community colleges and offering online, hybrid, or in-person associate degree programs for vector control.**
   Another unique aspect of our application is the fact that we are not only targeting university students, but also community college students. In particular, one of our partners, Salt Lake Community College (SLCC), is the most diverse institution in the State of Utah. The Intermountain STEPPES collaboration with SLCC will provide an opportunity to train the next generation of underrepresented students in STEM, which is even more important as SLCC is officially being designated as a Hispanic Serving Institution in the near future. This partnership will also allow students from SLCC vital field training which may lead to future employment within public health for many of the students.

7. **Support fellowships focused on medical entomology and the prevention and control of VBDs.**
   Our Intermountain STEPPES proposal is providing opportunities for development of a fellowship program at partnering academic institutions. In particular, we are supporting graduate students at both the University of Utah and also Utah State University. A post-doctoral fellow will also serve as a Training Coordinator through Utah State University and will assist with management, mentorship, training, field/laboratory assistance, and

overall facilitation and coordination between all students and VBD prevention and control professionals.

8. **Include vector-borne disease prevention and control curriculum in non-medical entomology degree programs, such as those in human or veterinary medicine, nursing, law, public health, or environmental health.**
   This component is being conducted with partnership at the University of Utah and Utah State University for public health and environmental health. Guest lectures in pertinent courses on various topics of vector-borne disease prevention and control will be provided to students in other degree programs. Internship opportunities will also be afforded to these students. We also aim to provide this same service to other academic institutions in Utah who have already partnered with us and provided letters of support, including Brigham Young University, Salt Lake Community College, Utah Tech University, Utah Valley University, and Westminster College.

STRATEGY 2: EVALUATE – Evaluate the impact and effectiveness of VBD prevention and control tools, strategies, and programs.

Our proposal has been built around providing real-world evaluations of vector control techniques used in the field. Some of these methods might be new in small MAD programs which do not have the funding, resources, manpower, or time to conduct routine surveillance and efficacy measures. We aim to place students and interns directly in these programs to assist with basic surveillance information which is crucial to evaluating the efficacy of any intervention method.

Required activities:

1. **Evaluate the operational use of approved VBD prevention and control tools, strategies, and programs.**
   Our proposal will standardize the evaluation of operational use of larvicides in peridomestic catch basins for Culex *larval control, and area-wide applications of adulticides for adult mosquito control via truck-mounted and fixed wing equipment. Because of the lack of funding, resources, manpower, or time to conduct routine surveillance and efficacy measures, many MADs do not currently undertake this task. However, our partnership and placement of students/interns within MADs will allow these evaluations to finally take place on a routine basis. The students will assist the MADs in conducting before-after-control evaluations and assist with enumeration, identification, pathogen testing, parity dissection, data entry, analysis, dissemination, and interpretation of results.*

2. **Implement/evaluate vector or VBD surveillance tools and programs.**
   The students/interns will assist the MADs in conducting before-after-control evaluations and assist with enumeration, identification, pathogen testing, parity dissection, data entry, analysis, dissemination, and interpretation of results. In many MADs this will be a newly implemented program, however, our aim is to provide a consistent and reliable evaluation scheme for all vector control programs in Utah. Although this implementation

will be largely led by students/interns during the grant, our aim is to instill these surveillance investigations within the vector control programs as a necessity and expect the programs to continue to conduct these evaluations on their own in perpetuity. VectorSurv will also be made available to all programs in order to expedite the dissemination of information amongst public health stewards and allow visualization of surveillance and control efforts for better informed decision making.

3. **Evaluate meaningful outcomes (reduction in vector abundance, biting rates, infection rates in vectors) of commercially available products when these products are applied by the intended end users (e.g., state and local health departments, pest control organizations, homeowners). Optimize and standardize implementation of these vector control products.**
   This will be conducted similarly as mentioned above. Metrics will be undertaken in regards to species presence/composition, species abundance, pathogen infection rates, proportion of parous individuals, and reduction of public service requests in regards to vectors.

4. **Evaluate health communication activities and products implemented at state, local, territorial, and Tribal levels; health communication messages should be coordinated with CDC technical advisors to ensure consistency with CDC messaging.**
   Our proposal includes a PI who serves as a full time Education/Outreach Specialist for Salt Lake City MAD. This individual will coordinate health communications amongst all partners and the CDC to ensure consistency with CDC messaging. We have partnered with the Utah Public Health Association to assist in providing accurate, relevant, and timely information to the public and stakeholders; Utah State Department of Health for tick and tick-borne disease messaging; Science Moab, a science communication non-profit organization in Moab where Ae. aegypti *has recently been detected and established to communicate pertinent information for local communities and visitors; Salt Lake County Health Department to prioritize PPE's and health education messages in an appropriate and culturally sensitive manner to at risk communities (lower income residents and unhoused individuals) through a new Health Equity Bureau within the Health Department to ensure health equity among populations most at risk; and the Utah Department of Corrections, which has built a new State Prison directly within wetland habitats where mosquitoes and mosquito-borne pathogens proliferate, to educate and train inmates and staff on vector control, prevention, and PPE methods for these highly at risk populations. Additional information on the specifics of each task highlighted above may be found in the accompanying letters of support.*

5. **Evaluate public health program implementations.**
   Evaluations of public health programs will follow the same guidelines as outlined above.

6. **Determine cost-effectiveness of VBD prevention and control tools, strategies, and programs, including for vaccines or vector control.**
   Incorporation of all new and existing vector control methods within MADs will be itemized and documented throughout the course of the grant funding cycle. The ultimate goal is to develop cost effectiveness outlines for vector control programs currently lacking proficiency and help convince funding authorities to invest sustainably in these programs for the long term.

7. **Evaluate community acceptance of VBD prevention and control tools, strategies, and programs, including for vaccines or vector control.**
   Vector control community acceptance will be conducted within new and established programs in partnership with our academic institutions, professional associations, and non-profit organizations.

STRATEGY 3: PARTNER – Build partnerships among relevant stakeholders to accomplish the activities proposed in Strategies 1 and 2.

Our proposal has been built an impressive and unique set of partners ranging from academic universities and colleges, public health departments at the state and county level, Native American Tribal Councils, professional associations, non-profit organizations, private industry, federal partners, State Departments of Agriculture and Corrections, and mosquito abatement districts to cover a large geographic area in the State of Utah (Figure 2).

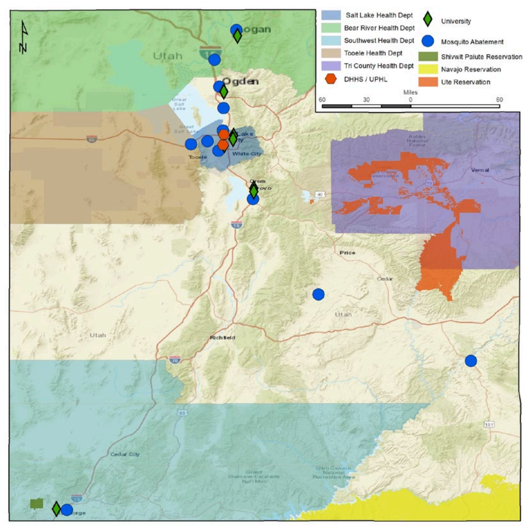

Figure 2. Geographic representation of partner agencies in the State of Utah.

Required activities:

1. **Establish collaborative partnerships in VBD prevention and control, involving relevant partners needed to develop and implement training and evaluation activities…**
   *Our proposal encompasses perhaps the largest interdisciplinary team assembled in the State of Utah for the prevention and control of vectors and vector-borne pathogens. All entities listed below have provided letters of support. This list includes **Mosquito Abatement Districts:** Utah Mosquito Abatement Association, Box Elder MAD, Cache MAD, MAD-Davis, Emery County Weed and Mosquito Department, Magna MAD, Moab MAD, Southwest MAD, Salt Lake City MAD, South Salt Lake Valley MAD, Tooele Valley MAD, Utah County Health Department Mosquito Abatement, and Weber MAD; **Native American Tribal Councils**: Utah Navajo Health System Public Health, Shivwits Band of Paitues, Ute Indian Tribe MAD; **Departments of Health:** Utah Public Health Association, Utah Department of Health and Human Services, Utah Public Health Laboratory, Bear River HD, Salt Lake County HD, Southwest Utah Public HD, Tooele*

County HD, TriCounty HD; ***Colleges and Universities (in state):*** *Brigham Young University (Public Health), Salt Lake Community College (Biology), University of Utah (Biology, Public Health, Atmospheric Sciences, Community Engaged Learning, Science Research Initiative), Utah State University (Biology), Utah Tech University (College of Science), Utah Valley University (Biology), Westminster College (Biology, Public Health, Great Salt Lake Institute);* ***Colleges and Universities (out of state):*** *Colorado State University (Center for Vector-Borne Infectious Diseases, College of Veterinary Medicine and Biomedical Sciences), University of California-Davis (Pacific Southwest Center of Excellence in Vector-Borne Diseases, Department of Pathology, Microbiology, and Immunology, School of Veterinary Medicine), Texas A&M University (College of Agriculture and Life Sciences);* ***Private Industry:*** *Clarke Mosquito Control, CoDiagnostics, Vector Disease Control International, Veseris;* ***Other State Departments:*** *Utah Department of Agriculture and Food (State Entomologist, State Veterinarian), Utah State Department of Corrections;* ***Non-Profit Groups:*** *National Audubon Society (Gillmor Wildlife Sanctuary); Science Moab Engagement Initiative (School to Science Program);* ***Federal Partners:*** *United States Department of Agriculture (National Bio and Agro-Defense Facility, Foreign Arthropod-Borne Animal Diseases Research Unit). Graduate, undergraduate and college students will be embedded in a multitude of these partner agencies for training, assistance, and betterment of public health.*

Collaborations

The Intermountain STEPPES program will be collaborating with all the above-mentioned entities within Utah and beyond. Many of these entities, particularly the Departments of Health, may be supported by the CDC directly or indirectly primarily through ELC funds. Additionally, we will be collaborating with the Pacific Southwest Center of Excellence in Vector-Borne Diseases, another entity directly funded by the CDC. Partnerships with other entities involved in training, prevention, and control for public health purposes will also occur with a multitude of agencies listed above.

Target Populations and Health Disparities

Throughout this proposal we have highlighted the target population of the proposal, with a special emphasis on populations that may lower in income, in rural areas, and members of minority communities that may experience a higher burden of mosquito bites and vector-borne pathogen infections. Partnerships are being particularly developed with Native American Tribes. We will work with our academic and health department partners to ensure the latest health equity approaches are being implemented.

Applicant Evaluation and Performance Measurement Plan

All activities of the Intermountain STEPPES program will be evaluated for efficacy and performance by the core group of PI's at Salt Lake City MAD, University of Utah (Biology and Public Health Departments), and Utah State University. Additionally, the Program Coordinator at SLCMAD and Post-Doctoral Fellow at USU will implement specific performance measurement plans to be used by all partners. Quarterly meetings will be held by all partnering agencies. Additionally, an expert panel of external reviewers will be assembled from neighboring institutions (including CDC personnel at DVBD and Centers of Excellence) to oversee the implementation and evaluation of performance metrics. Key evaluations will include the efficacy of training campaigns at the annual workshop and placement of students/interns within vector control programs, impact of public outreach activities and knowledge of vectors and vector-borne pathogens, and efficacy evaluations of larvicide and adulticide campaigns under operational settings. A full DMP will be provided if the proposal is funded.

Organizational Capacity of Applicants to Implement the Approach

The Intermountain STEPPES program is composed of entities ranging from government to academic to non-profit and private industry organizations. Many of these programs are responsible for millions of dollars in annual revenues and must comply with government accountability and compliance standards. The core group of investigators have expertise in federal granting, human resources, budgeting, personnel management, good laboratory practices, transparency, reporting, and overall liability. We have no doubt that the assembled group of leaders possess the organizational capacity to administer and implement the various approaches stated within the proposal.

Work Plan

The Work Plan for the Intermountain STEPPES program will be divided into two major components centering on Training and Evaluations.

Training:

Training of students and public health professionals will be composed of two major components. The first will consist of a combination of classroom, laboratory, and field experiences for trainees. A mixture of lectures, presentations, case studies, hands-on equipment training, vector identification, and field/semi-field sampling will be offered. These lectures and workshops will be led by various team members from the MADs to the health departments and academic institutions, and will include topics such as integrated vector management techniques, best management practices, pesticide safety, active ingredient mode of action, pesticide selection, calibration of vector control equipment, determination of application rates, personal protection equipment, bioassays for determination of efficacy, insecticide resistance monitoring, vector (mosquito and tick) biology/ecology, field epidemiology, arbovirology, disease ecology, vector (mosquito and tick) surveillance techniques, vector (mosquito and tick) identification, habitat recognition, species bionomics, Before-After Control-Impact evaluation, good laboratory practices, molecular techniques, pathogen testing, data entry for statewide dissemination of surveillance data using VectorSurv, arthropod husbandry, and public outreach, amongst many other activities. In addition to our academic partners and public health specialists who already hold expertise in mentorship and providing this type of training, two of the PI's from Salt Lake City MAD have been certified as Master Trainers and have led similar workshops and Train-the-Trainer events around the United States on best management practices for invasive Aedes surveillance and control. Our annual training will mimic those workshops and provide an active training for attendees where real-world scenarios and case studies will be presented. A large benefit of this workshop will be the capability of providing financial assistance for all partnering academic institutions within Utah to send interested students to the workshop. Additionally, our partners at the University of Utah's Public Health Department will develop up to five modules on vector-borne disease prevention and control to be used in a variety of educational programs (undergraduate and graduate level public health, environmental health, health education, and occupational health as well as undergraduate and graduate medical education) and for existing professionals. These modules will be available to all partnering educational institutions in Utah (and surrounding states) and/or through the existing University of Utah Public Health Learning Management System. Last, in years 4-5 of the grant, we aim to create a graduate/undergraduate academic course offered jointly through the University of Utah and Utah State University (USU). USU is a land grant institution that is devoted to providing high quality affordable educational opportunities to students who might not otherwise have access. USU's statewide program includes 8 campuses and 23 education centers across the state, with a total of 30 locations with broadcasting capabilities across the state. The network allows students in rural communities to remotely attend courses being broadcast from any USU campus. Here we propose to leverage the pre-existing infrastructure to provide opportunities for students in rural areas to collaborate with faculty and education specialists, professionals, other trainees, and vector control experts across the state without having to leave their communities and obligations at home. Although it is well documented that this type of education and technical training can provide individuals with increased access to job opportunities, networking opportunities, and earning potential, young people from rural areas remain less likely to attend university than their urban counterparts. Additionally, many rural USU campuses serve high percentages of first generation (nearly 40% of students at the Price campus are first generation), and underserved populations (USU Blanding is designated as a "Native American Serving Nontribal Institution"). While this gap in educational attainment in these groups arises from both practical and perceived barriers, if awarded, the CDC training and evaluation grant, can bring high quality training directly to the students that will benefit from it the most. We will also work with other academic institutions in the state to allow for cross attendance and credit for interested students.

The second component of training consists of placement of students directly into the field as interns and summer employees at various MADs, health departments, and Native American Tribal programs. Many of the smaller vector control operations in the state do not have the resources, equipment, or personnel in order to conduct evaluations of abatement measures. This partnership will strategically place students from nearby colleges/universities within vector control units to assist with evaluations, while also providing enormous field experience training for the students to complement their academic experiences and allow them to become well-rounded public health specialists. It is imperative for the next generation of public health stewards to not only understand disease epidemiology, but also acquire hands-on experience with field surveillance, pesticide science and safety, and effective intervention methods. In addition to gaining field experience with various aspects of vector surveillance and control, the students will also gain valuable practice with interacting with the public and various user groups and understanding effective communication strategies, a skill that they will undoubtedly need in their future endeavors. Additionally, one of our partners at Utah State University will provide a post-doctoral fellow, who will also act as the Training Coordinator on our proposal. This individual will not only be trained according to the above, but will also serve as a direct mentor for additional undergraduate and graduate students during the entire course of this grant. The overall goal is to develop a well-informed student body who are competently trained in all aspects of vector surveillance and control, and are capable to hit the ground running upon placement in the workforce.

Evaluations:

Evaluation of vector control intervention methods will be composed of two major components. The first will standardize the evaluation of operational use of larvicides in peridomestic catch basins for *Culex* larval control, and the second will evaluate the area-wide applications of adulticides for adult mosquito control via truck-mounted and fixed wing equipment. Because of the lack of funding, resources, manpower, or time to conduct routine surveillance and efficacy measures, many MADs do not currently undertake this task. However, our partnership and placement of students/interns within MADs will allow these evaluations to finally take place on a routine basis. The students will assist the MADs in conducting before-after-control evaluations and assist with enumeration, identification, pathogen testing, parity dissection, data entry, analysis, dissemination, and interpretation of results.

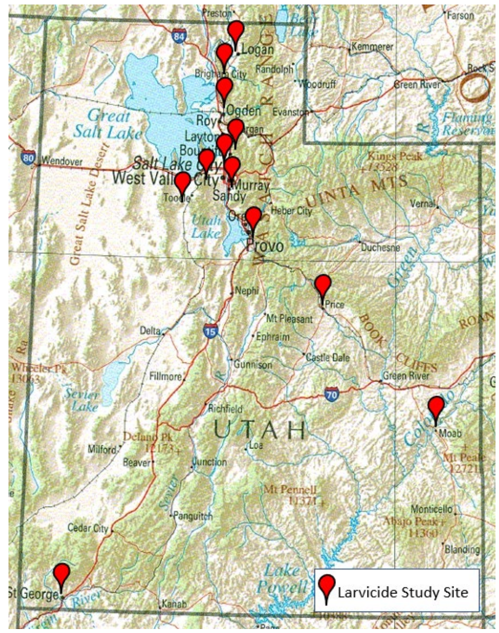

Figure 3. Location of larvicide evaluations with partner agencies.

For the larvicide evaluations, catch basins used in evaluations will be selected based on the presence of immature mosquitoes at an adequate water depth. The larvicide product used will be the insect growth regulator Sumilarv WSP (MGK, Minneapolis, USA) with the active ingredient of pyriproxyfen at 0.5%. Twelve vector control programs will participate in the evaluations (Figure 3). Fifteen catch basins will be used for each condition (treated and untreated). Treated catch basins will have three WSP packets applied, which is 75g of product. Fifteen similar catch basins will be left untreated for evaluation.

Treatments will take place at the beginning of the mosquito season (April or May). Inspections to help evaluate the effectiveness of treatments will be performed every two weeks with student/intern assistance, until the end of the mosquito season (September or October). At each inspection, four dips will be collected, from which 3rd and 4th instar larvae and pupae will be counted to determine per dip averages. Pupae at each basin will be saved in a unique plastic collection cup. At least 10 pupae will be collected, if possible, from each basin. More dips than four can be conducted to collect the 10 pupae. The plastic cups with pupae will be transported to a laboratory and reared at room temperature. Pupae will be checked regularly for emergence and percent inhibition. The emerged adult mosquitoes and a subsample of larvae will be identified to species. The catch basins will be sampled by use of a specialized dipper that has a quickly changeable cup holder. These dippers will be 3D printed by Salt Lake City MAD staff and made available to all partners. Containers used in the dippers are disposable plastic cups that are used for just a single sampling event. The cup holders are also changed out between catch basins, but they are reused for the duration of the study. The cup holders are labeled so that each cup holder is used for just a single basin during the evaluation. Between larval samplings, the holders will be cleaned by being wiped down and left outside with sun exposure for at least one week. The water samples will be removed and dumped into a white plastic tub where egg rafts, larval, and pupal stages are counted. Each catch basin will be measured and depth determined.

The efficacy of Sumilarv treatments will be determined for each bi-weekly collection. Bi-weekly collections will occur for the active mosquito season. Efficacy will be determined by an Inhibition of Emergence (IE) formula: IE = 100-100(T/C) where T is percent emergence in each treated catch basin, and C is mean percent emergence in all untreated control catch basins. A value of 100% indicates that no adults emerged and a value of 0% indicates successful emergence from all the pupae. A given catch basin was eliminated from consideration when the IE dropped to 70% or less, twice, indicating that more than 30% of the pupae emerged to become viable adults. The weather conditions at the evaluation locations will be monitored daily by utilizing local weather stations. Specific conditions or important events affecting catch basins will be noted. All data will be tabulated by students/interns, and overseen the by Program Coordinator.

For the adulticide evaluations, three major components will be evaluated consisting of wind tunnel evaluations, truck-mounted ground applications, and aerial fixed-wing applications. The evaluations will be conducted with all partnering MADs in the State of Utah (Figure 2). Because of the budget, size, and personnel within the various MAD's, only three districts will conduct aerial evaluations, while all will evaluate truck-mounted ground applications. Aerial adulticide products will consist of Dibrom Concentrate (AMVAC Chemical Corporation, Newport Beach, CA) containing an organophosphate active ingredient of Naled (87.4%). Application rate will be intended at 55 ml/ha (0.75 oz/acre). Ground adulticide products will consist of Duet (Clarke Mosquito Control Products, Inc., Roselle, IL), containing Prallethrin (1.0%), Sumithrin (5.0%), and PBO (5.0%). Application rate will be intended at 146 ml/ha (2.0 oz/acre). Other adulticides may be added based on MAD polling and usage. All products will be tested against laboratory (susceptible) and field populations of mosquitoes. Laboratory evaluations will use insectary-sourced colonies of *Aedes aegypti* (1952 Orlando strain), *Culex tarsalis* (SAC-YOLO strain), *Culex pipiens/quinqeufasciatus* (2016 SLCMAD strain/1952 Orlando strain). For comparison, field-sourced colonies of *Ae. aegypti* (present in Moab, UT), *Aedes dorsalis* (statewide nuisance), *Cx. tarsalis* (statewide rural vector), and *Cx. pipiens/quinquefasciatus* (statewide urban vector) will also be used in laboratory evaluations. Field evaluations will use wild populations of nuisance and vector mosquitoes, to include *Cx. tarsalis, Cx. pipiens, Ae. dorsalis,* and *Aedes vexans*. Evaluations will be conducted using harmonized pesticide application practices and surveillance techniques across multiple participating mosquito abatement districts. Laboratory evaluation will be conducted primarily at the Salt Lake City MAD laboratories. Field participants will represent multiple climate regions of Utah. Academic partners will assist MADs with field work through placement of students at each district to assist with field sampling, monitoring, bioassays, identification, etc. as needed. This will provide valuable field training for all students. Subsequent years can expand on the investigations with product rotation, evaluating different ULV products such as ReMoA Tri (Resistance Mode of Action: Tri, Valent Biosciences LLC, Libertyville, IL). All evaluations will be interpreted at both the local level and across the entire state to infer the best course of future operations for all program participants.

For the Wind Tunnel Evaluations, MADs will be polled on the ULV adulticide products in circulation within their programs; all adulticides selected for evaluation will be derived from the poll results. Field collections will be made opportunistically among regionally separated populations (ex: *Ae. dorsalis* sourced from both Salt Lake City and Weber counties as separate strains). Strains will be isolated within $F_0 – F_6$. Comparisons will be made to relevant laboratory species/strains. An equal number of negative controls will be paired with product treatments. The test substance(s) will be withdrawn from storage and kept in laboratory conditions maintained at 23±5°C for a minimum of 24hrs in advance of use in a wind tunnel. The evaluations will be conducted via direct spray application to mesh-topped, cylindrical cages (ex: 63.617cm^2 footprint). One replicate consists of 15 individuals of a single species all being adult, non-blood fed, female mosquitoes less than 12 days of age. Cages intended for treatment will be loaded into a pre-fabricated wind tunnel developed at the Salt Lake City MAD (Figure 4). Cages will be locked in-line for correct orientation within the wind tunnel. Treatment will be applied over the entire 53.34 cm (21 in) × 15.24 cm (6 in) cylindrical length of the wind tunnel, covering a static 2,919 cm, or 0.3 m^2 (452 in^2, or 3.14 ft^2) during a 3-second burst from an airbrush gun (WHO 2009). Product will be applied in as much additional diluent as necessary to make application logistics reasonable and accurate for the machinery available while abiding the label restricted deposition per acre. Within 15 min following treatment, mosquitoes will be returned to the laboratory and transferred into untreated holding containers supplied with 10% sucrose solution. The first knockdown (KD) and mortality (M) data measure will be at 2 hr post treatment, after which mosquitoes in both treatment and control cohorts will be transferred to clean holding cages. Final mortality will be measured between 12-24 hr post-treatment. Products will be evaluated at each of their low, middle, and high rates prescribed on the EPA approved label. Evaluations will be replicated three times at each rate, per product, per species included. Knockdown (KD) will be recorded as test systems that are unable to fly or navigate normally, and which may exhibit various signs of ataxia shortly after exposure to treatment. Mortality (M) will be recorded as test systems that are unresponsive to stimuli; may also be accompanied by signs of decay such as discolored body or contaminant growth.

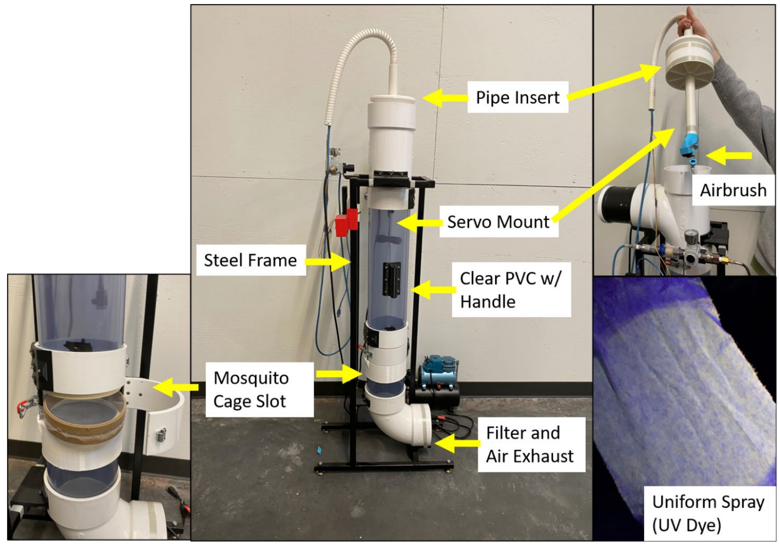

Figure 4. Wind tunnel system developed at Salt Lake City MAD for evaluation of adulticide products.

For ground truck-mounted applications, up to twelve participating MADs will participate to represent three separate geographic areas (North, Central, and Southern Utah). Evaluation will involve up to 50 acres of tract, whether contiguous or not, mapped out in high mosquito pressure areas containing accessible roads. Equipment will consist of a truck-mounted ULV machine (Ex: Grizzly ULV Sprayer, Clarke Mosquito Control Products, Inc., or equivalent), calibrated to 15-20 µm target VMD. Duet will be dispensed at a rate of 146 ml/ha (2.0 oz/acre). Treatments will be conducted when wind speed is ideally 1.6-16 kph (between 1-10 mph). Swath width will be estimated at 100 m (300 ft) linear measurement. Applications will be made at crepuscular time windows of primarily evening (ex: within 2 hrs of sunset). If a district has a large unbroken spray block for use in ground evaluation, then all surveillance sites will be distributed approximately 1 site per 5 acres of treated land, contingent upon accessibility. Any non-contiguous tract included for ground spray blocks will have at least one surveillance site per fragment. Surveillance cycles will consist of CO_2 emitting traps, allocated according to spray block patterns. Traps will be placed approximately 1.5 m (4 – 5 ft) above the ground. All traps will be baited with 400 ml/min of CO_2, such as via a pressure regulated canister. Abiotic data will be retrieved from the nearest relevant weather station in service. If no relevant stations are adjacent to spray blocks, then a weather monitoring device will be placed inside the spray block. Temperature, humidity, wind direction, and wind speed will be recorded on record sheets. Initial surveillance will be conducted 24 hr before the treatment application and then redeployed for the 24 hrs following treatment to evaluate effectiveness of the operations on mosquito populations. Mosquito collections will be returned to the lab for sorting and quantification using a combination of light microscopy and other tools as needed; for example, digital cataloguing (ImageJ, National Institute of Health) according to methods in Kesavaraju and Dickson (2012). For each trap, speciation will occur after sub-sampling of the collection contents, up to ~300 adults per sub-sample. Sub-samples (or entire trap contents, if collection total is less than the sub-sample cutoff) will be sorted for two population metrics: one sub-sample will be dedicated for mosquito pools and viral DNA extraction to confirm mosquito infection; a second sub-sample will be dedicated to parity dissection to age-grade the collected mosquitoes. If multiple sub-samples cannot be taken from a surveillance site, then the single sub-sample will have abdomens cut and stored separated from thoraxes. Isolated abdomens will be used in parity dissection and tissue remainders will be processed in mosquito pools. Any dissection samples, either intact or isolated abdomens, that cannot be dissected fresh will be labeled, immersed in 70% isopropyl/etOH, and stored in a freezer until ready to process. Surveillance cycles will be repeated a minimum of 3 times per treatment type across participating abatement districts. Evaluations may be replicated more if necessary to strengthen the inference.

For aerial fixed-wing applications, Salt Lake City MAD, MAD-Davis, and Weber MAD will utilize aircraft to conduct mosquito adulticide applications over large wetland habitats surrounding the Great Salt Lake. Evaluation will involve a 5,000+ acre spray block drawn over pertinent mosquito habitat outside of major urban centers. Equipment will consist of an appropriate fixed-wing aircraft (ex: Piper Aztec II) and rotary atomizers (Micronair AU5000, Micron Sprayers Ltd., UK, or equivalent). Outputs will be calibrated to 35-40 µm target VMD. Due to high specific gravity of Dibrom/Naled, droplets closer to 35 µm average (as opposed to closer to 40 µm average) will be sufficient for drift management. Naled will be dispensed at a rate of 55 ml/ha (0.75 oz/acre). Treatments will be conducted when wind speed is ideally 1.6-16 kph (between 1-10 mph). Flight trajectory will occur anywhere from 24-91 m (80-300 ft) above the ground, at pilot discretion of safety. Applications will be made at crepuscular time windows of primarily evening (ex: within 2 hrs of sunset). Spray blocks will contain a minimum of 5 sites, approximately equidistant from each other, selected for a surveillance cycle.

Statistical analysis of data will be conducted using Abbott's formula used to adjust for mortality in the control. Abbott's formula: $((A – B) / A) X 100$ where A: % live in control and B: % live in treated. Percent mortality will be calculated using the following formula: % Mortality = $((1-(C/D)) X 100$ where C: number living arthropods and D: total number of arthropods. For trap surveillance, percent reduction will be conducted according to Mulla et al. 1971's application of the following formula: $[1 - (C_1 \times T_2)/(T_1 \times C_2)] \times 100$ = Percent Reduction where C_1 = Mosquitoes released of target species in placebo, C_2 = Placebo count at time corresponding with treatment count, T_1 = Mosquitoes released of target species in treatment, and

T_2 = Treatment plot count. Additional post-hoc analyses will be conducted as needed; the anticipated platform for analysis will be R statistical software (v4.2.1 or greater, The R Foundation for Statistical Computing, Vienna, Austria) via R-Studio (v. 3.3.0 or greater, RStudio PBC, Boston, MA). Requisite packages will be reported after completion. Further statistical modeling will be fully described in the final report with outputs presented. For example, Before-After Control Impacts (BACI) may be analyzed according to Rochlin et al 2022. Inference will be improved by incorporating age-grading assessment and presence of infected mosquitoes as their own variables. All students and interns will actively assist the MADs in laboratory and field evaluations during the course of the funding cycle.

References

AMCA (American Mosquito Control Association). 2017a. Best Practices for Integrated Mosquito Management: A Focused Update. AMCA. Sacramento, California. Available from: https://cdn.ymaws.com/www.mosquito.org/resource/resmgr/docs/publications/amca_guidelines_final_pdf.pdf

AMCA (American Mosquito Control Association). 2017b. E-Modules: Understanding and controlling the Zika virus – Overview, Behavior, Surveillance, Control. https://www.mosquito.org/page/EModules. Accessed 1 February 2023.

Beard, CB; Visser, SN; Petersen, LR. 2019. The need for a national strategy to address vector-borne disease threats in the United States. Journal of Medical Entomology. 56: 1199-1203.

CDC (Centers for Disease Control and Prevention). 2013. West Nile virus in the United States: Guidelines for surveillance, prevention, and control. https://www.cdc.gov/westnile/resources/pdfs/wnvguidelines.pdf. Accessed 1 February 2023.

CDC (Centers for Disease Control and Prevention). 2020. Vector-borne diseases in the US. https://www.cdc.gov/ncezid/dvbd/vital-signs/index.html. Accessed 1 February 2023.

CDC (Centers for Disease Control and Prevention). 2021. West Nile virus disease cases reported to CDC by state of residence, 1999-2021. https://www.cdc.gov/westnile/statsmaps/cumMapsData.html. Accessed 1 February 2023.

Eisen, RJ; Eisen, L; Beard, CB. 2016. County-scale distribution of *Ixodes scapularis* and *Ixodes pacificus* (Acari: Ixodidae) in continental United States. Journal of Medical Entomology. 53: 349-386.

Elkashef, S. 2019. Evaluation of Sumilarv 0.5G in catch basins in Sacramento and Yolo Counties. Proceedings and Papers of the Mosquito and Vector Control Association of California 87: 60-61.

Faraji, A; Unlu, I. 2016. The eye of the tiger, the thrill of the fight: Effective larval and adult control measures against the Asian tiger mosquito, *Aedes albopictus* (Diptera: Culicidae), in North America. Journal of Medical Entomology. 53: 1029-1047.

Farajollahi, A; Fonseca, DM; Kramer, L; Kilpatrick, AM. 2011. Bird biting mosquitoes and human disease: A review of the role of the *Culex pipiens* complex in epidemiology. Infection, Genetics and Evolution. 11: 1577-1585.

Farajollahi, A; Healy, SP; Unlu, I; Gaugler, R; Fonseca, DM. 2012. Effectiveness of ultra-low volume nighttime applications of an adulticide against diurnal *Aedes albopictus*, a critical vector of dengue and chikungunya viruses. PLoS One. 7: e49181.

Gloria-Soria, A; Faraji, A; Hamik, J; White, G; Amsberry, S; Donahue, M; et al. 2022. Origins of high latitude introductions of *Aedes aegypti* to Nebraska and Utah during 2019. Infection, Genetics and Evolution. 103: 105333.

Gubler, DJ. 1998. Resurgent vector-borne diseases as a global health problem. Emerging Infectious Diseases. 4: 442-450.

Hahn, MB; Eisen, L; McAllister, J; Savage, HM; Mutebi, JP; Eisen, RJ. 2017. Updated reported distribution of *Aedes* (*Stegomyia*) *aegypti* and *Aedes* (*Stegomyia*) *albopictus* (Diptera: Culicidae) in the United States, 1995-2016. Journal of Medical Entomology. 54: 1420-1424.

Haile, DG; Mount, GA; Pierce, NW. 1982. Effect of droplet size of malathion aerosols on kill of caged adult mosquitoes. Mosquito News. 42: 576-583.

Kesavaraju, B; Dickson, SL. 2012. New techniques to count mosquito adults: Using Image J software to estimate number of mosquito adults in a trap. Journal of the American Mosquito Control Association. 28: 330-333.

Krow-Lucal, ER; Novosad, SA; Dunn, AC; Brent, CR; Savage, HM; Faraji, A; et al. 2017. Zika virus infection in patient with no known risk factors, Utah, USA, 2016. Emerging Infectious Diseases. 23: 1260-1267.

Lounibos, LP. 2002. Invasions by insect vectors of human disease. Annual Review of Entomology. 47: 233-266.

Mount, GA. 1998. A critical review of ultra-low volume aerosols of insecticide applied with vehicle-mounted generators for adult mosquito control. Journal of the American Mosquito Control Association. 14: 305-334.

Mulla, MS; Norland, RL; Fanara, DM; Darwezeh, A; McKean, DW. 1971. Control of chironomid midges in recreational lakes. Journal of Economic Entomology. 64: 300-307.

NACCHO (National Association of County and City Health Officials). 2017. Mosquito Control Capabilities in the U.S. https://www.naccho.org/uploads/downloadable-resources/Mosquito-control-in-the-U.S.-Report.pdf. Accessed 1 February 2023.

NACCHO (National Association of County and City Health Officials). 2020. Vector Surveillance and Control at the Local Level. Findings from the 2020 Vector Control Assessment. https://www.naccho.org/uploads/downloadable-resources/Vector-control_2020-assessment-report_Final.pdf. Accessed 1 February 2023.

Patterson, G. 2009. The Mosquito Crusades: A History of the American Anti-Mosquito Movement from the Reed Commission to the First Earth Day. Rutgers University Press, New Brunswick, New Jersey.

Rochlin, I; Benach, JL; Furie, MB; Thanassi, DG; Kim, HK. 2023. Rapid invasion and expansion of the Asian longhorned tick (*Haemaphysalis longicornis*) into a new area on Long Island, New York, USA. Ticks and Tick-borne Diseases. 14: 102088.

Rochlin, I; White, G; Reissen, N; Martheswaran, T; Faraji, A. 2022. Effects of aerial adulticiding for mosquito management on nontarget insects: A Bayesian and community ecology approach. Ecosphere. 13: e3896.

Ronca, SE; Ruff, JC; Murray, KO. 2021. A 20-year historical review of West Nile virus since its initial emergence in North America: Has West Nile virus become a neglected tropical disease? PLoS Neglected Tropical Diseases. 15: e0009190.

Su, T; Thieme, J; White, GS; Lura, T; Mayerle, N; Faraji, A; et al. 2019. High resistance to *Bacillus sphaericus* and susceptibility to other common pesticides in *Culex pipiens* (Diptera: Culicidae) from Salt Lake City, UT. Journal of Medical Entomology. 56: 506-513.

UMAA (Utah Mosquito Abatement Association). 2023. Districts. https://www.umaa.org/districts. Accessed 1 February 2023.

WHO (World Health Organization). 2009. Guidelines for efficacy testing of insecticides for indoor and outdoor ground-applied space spray applications. WHO Pesticide Evaluation Schemes. pp. 54.

World Population Review. 2023. Mormon population by state, 2023. https://worldpopulationreview.com/state-rankings/mormon-population-by-state. Accessed 1 February 2023.