As members of the Master’s Committee, we certify that we have read the thesis prepared by Joshua Arnbrister, titled “Engaging Community Health Workers in Mosquito Control and Surveillance in an Urban Desert Environment” and recommend that it be accepted as fulfilling the dissertation requirement for the Master’s Degree.

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Final approval and acceptance of this thesis is contingent upon the candidate’s submission of the final copies of the thesis to the Graduate College.

I hereby certify that I have read this thesis prepared under my direction and recommend that it be accepted as fulfilling the Master’s requirement.

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Abstract

This project examined the practicality of partnering with community health worker organizations in southern Arizona to conduct larval surveillance for the *Aedes aegypti* mosquito. In this study community health workers were trained using a one-day didactic classroom training on mosquito-borne disease and surveillance, followed by a hands-on larval surveillance training. Pre- and post-survey scores given before and after the didactic training indicate a significant increase in knowledge about mosquito-borne disease and surveillance. Furthermore, during the first mosquito season community health workers successfully collected mosquito larval samples, showing proof of principle for CHW in mosquito surveillance. Logistical issues prevented community health workers from conducting household mosquito surveillance during the second mosquito season. These findings indicate that while training is effective, competing responsibilities may limit the capacity of community health workers to conduct mosquito surveillance.
Chapter 1-Community Health Worker Literature Review

Introduction

Community health workers have a long history in public health efforts, which can be difficult to elucidate due to an abundance of different titles and definitions for their role. For the purposes of this study we will use the definition given by the 2007 Community Health Worker National Workforce Study:

Community health workers are lay members of communities who work either for pay or as volunteers in association with the local health care system in both urban and rural environments and usually share ethnicity, language, socioeconomic status and life experiences with the community members they serve (U.S. Department of Health and Human Services et al., 2007).

The first recorded program matching this definition was the use of lay people in China during the 1920’s to record health data, give vaccines, first aid, and health education talks. This later became the Barefoot Doctor program (Lehmann & Sanders, 2007; Perry et al., 2014). In the United States, the first community health worker programs emerged during the 1960’s as part of an initiative to provide health services to American Indian populations (Landond et al., 2003; U.S. Department of Health and Human Services et al., 2007; Witmer et al., 1995). Community health worker programs expanded internationally through the 1970s and 80s, with recognition of their importance written into the 1978 Alma-Ata Declaration. The economic recession in the 1980s led to a reduction of programs in many countries, but many programs have survived until the modern day (Lehmann & Sanders, 2007; Perry et al., 2014).

In the United States, community health workers have been particularly important in reaching underserved populations cut off from traditional healthcare by language, culture, or economics, especially among Latinx communities. In 1999, programs were launched in both Texas and New Mexico to train community health workers in environmental health hazard recognition and prevention in Spanish-speaking colonias along the U.S.-Mexico border (Forster-Cox et al., 2010; Ramos et al., 2001). In the same year, Texas passed legislation to certify community health workers, followed by the American Public Health Associations recognition of community health workers as public health professionals (Bovbjerg et al., 2013). In 2007, most community health workers operated in Latinx and African
American communities. Approximately 82% of the community health workers in the U.S. were female. Around 35 percent had a high-school diploma, while 51 percent had completed some college work or obtained a four-year degree. The most common fields for community health workers in the United States in 2007 were women’s and child health, nutrition, immunizations, and pregnancy/prenatal care. There were also programs targeting chronic illness such as cardiovascular disease, diabetes, and high blood pressure, as well as programs focused on HIV/AIDS and cancer (U.S. Department of Health and Human Services et al., 2007). As of May 2018 it is estimated that there are 56,130 community health workers employed in the United States, with an average wage of $20.90 per hour (Bureau of Labor Statistics, 2019).

Community health workers in the United States have been engaged across many areas. One field lacking community health worker involvement is vector-borne disease, surveillance and control. Vector-borne disease accounts for 17% of all global infectious disease cases (World Health Organization, 2017). Engaging community health workers in vector surveillance and control is one strategy to reduce this burden. Some areas of the United States, including Arizona, are at risk for local vector-borne disease such as dengue and Zika, due to the presence of Aedes aegypti in highly populated urban centers, and movement into the United States of disease related viruses from the neighboring Mexican state of Sonora (Border Infectious Disease Surveillance Program, 2018, 2019; Tarter et al., 2019). Arizona has a strong community health worker presence as demonstrated by the foundation of the Arizona Community Health Workers Association in 2001 (AzChow, 2019). These factors make Arizona uniquely situated to test the feasibility of a community health worker mosquito surveillance project in the United States.

This review will primarily focus on how to employ and educate community health workers in mosquito surveillance. Community health worker successes will be analyzed in three fields related to mosquito surveillance: environmental and occupational health, malaria treatment and prevention, and mosquito surveillance. Success and challenges in each program will be discussed, and how these issues affect an Arizona based mosquito surveillance project.
Environmental and Occupational Health

Community health worker programs have a history of involvement in environmental and occupational health. In 1999, the Center for Environmental and Rural Health at Texas A&M University partnered with the Center for Housing and Urban Development and the South Texas Promotora Association to launch an environmental health pilot program in colonias along the U.S.-Mexico border. A “train-the-trainer” model was used with the goal that promotoras, a Spanish term for community health workers, would be educated on environmental health hazards and provide education to their neighbors in the colonias. Promotoras were given behavioral modification “safety tips” and were evaluated on what they learned. They were then sent into the community to provide educational sessions to neighbors and residents. The main finding of this program was that promotoras are effective educators because they provide culturally sensitive and relatable trainings due to their close relationship with the communities, they work in. They also provided valuable feedback to refine the design and implementation of the community health worker trainings and the program in general (Ramos et al., 2001).

A similar project, the Environmental Health/Home Safety Education Project, was launched the same year in colonias in New Mexico. This project was a collaboration between the Southern Area Health Education Center and the Border Health Education Training Center of New Mexico University with funding from the New Mexico Department of Health, Office of Border Health. The project aimed to conduct environmental health home assessments and provide educational outreach to remedy any dangers found, such as lack of smoke detectors or presence of lead. The community health workers were trained in several environmental health topics including food safety, indoor air pollution, and safe pesticide storage. Home visits were conducted to assess environmental health hazards, with follow up visits to determine if suggested steps had been taken to deal with identified hazards. Community health workers found a host of environmental health hazards in homes such as lack of window screens, improper gas tank storage, improper pesticide storage, and lack of operational fire extinguishers. Incentive packages were designed to be given to community participants, which included educational materials, pencils, emergency numbers, and smoke detectors. By 2005 the project had conducted more than 400
presentations, provided services to over 700 families, and was being replicated across New Mexico (Forster-Cox et al., 2010).

Some programs focus broadly on environmental health and others target very specific health objectives. An occupational health program based in southeastern Michigan and Northern Illinois involving community health workers was launched in 2001, with the goal of reducing eye injuries among Latino farm workers. The study recruited sixteen community health workers who were given training on eye injury and prevention, educational outreach, and data collection. Input from community health workers was used to refine the trainings. The study was conducted on 36 farms broken into blocks A, B, C, and control. In Block A, community health workers were employed as farm workers, distributed safety gear and information sheets, and provided in-person safety trainings. In Block B, community health workers only distributed safety glasses and information sheets. In Block C, safety glasses and information sheets were distributed by research team members instead of community health workers. Study participants across all blocks were more likely to wear protective eyewear than control groups. However, those in Block A were more likely to utilize protective eyewear than those in Blocks B and C. Furthermore, participants in Block B were more likely to use protective gear than those in Block C. While this study was not able to draw conclusions on eye injury reduction due to the intervention, they did find community health workers to be effective in promoting personal protective equipment, and providing safety education on workplace injury (Forst et al., 2004).

The position of trust that community health workers hold within their communities, and their awareness of the communities’ culture make them uniquely suited to provide effective environmental and occupational health education. The invasive nature of health inspections can be mitigated by employing culturally sensitive individuals known within the community, thus making communities more open to the provided education and solutions.

Malaria Treatment and Prevention

A multitude of community health worker programs have been launched internationally to deal with issues related to communicable diseases. One of the major diseases that community health worker
projects have targeted is malaria. Malaria is one of the highest burden single diseases globally. It is also preventable with proper prevention and treatable with early detection and medication. As of 2018 there were 228 million cases of malaria worldwide, with 213 million cases occurring in sub-Saharan Africa. This is a steep decline from decades past, though reductions have not been distributed evenly across the world (World Health Organization, 2019). Community health workers have been integral to the reduction in malaria acting to diagnose, treat, and prevent malarial infection in multiple regions worldwide often in hard-to-access communities.

Between 1992 and 1995 a community health worker malaria education project was tested in Nicaragua, Colombia, and Ecuador. The project began with a household survey in communities to establish baseline knowledge of malaria epidemiology, prevention, treatment, and preventative measures taken by the community. Community health workers were recruited and given monthly trainings on malaria control, epidemiology, treatment, prevention. Once trained, the community health workers held community meetings and workshops to educate their communities on malaria treatment and prevention. Overall it was found that knowledge of malaria etiology and symptoms increased by 33 to 61 percent in communities with the community health worker intervention compared to control communities (Kroeger et al., 1996).

In 2001 the Village Malaria Worker project was launched in Cambodia. The project was composed of 315 villages with two village malaria workers, one male and one female, per village. Malaria workers were chosen by community members and participated in a three-day training on rapid diagnostics testing, malaria treatment, hospital referrals, and case documentation. Village malaria workers were tasked with performing rapid diagnostic tests on villagers and providing correct doses of medication if results were positive. A survey was distributed to village malaria workers to determine the quality of their service, what malaria prevention measures they took, and assessing their knowledge of malaria epidemiology and vector ecology. It was found that the community health workers provided effective service in rapid diagnostic testing, prescribing medication, and other areas they received extensive training on. However, workers struggled to provide services in areas they received limited training on,
such as malaria epidemiology, actively seeking out malaria cases, and malaria symptom diagnosis (Yasuoka et al., 2010).

A similar project was launched in eastern Kenya in 2007. The main goal of the study was to investigate if a community health worker intervention could increase community knowledge of malaria epidemiology and increase the use of insecticide treated bed nets. The study included 75 villages, with two community health workers recruited from each village. Community health workers attended a five-day training course on malaria control, childhood disease, hygiene, child nutrition, reproductive health, HIV/AIDS, and communication. Health workers then held educational sessions about malaria and proper use of insecticide treated nets in their villages, specifically targeting mothers of small children, and distributed insecticide treated nets among the villagers. Pre- and post-surveys were conducted in the villages to determine the villagers’ knowledge about the cause of malaria, and bed net ownership and proper use. The results of this project showed that villagers had a 12% increase in correct identification of the cause of malaria, and an 18% increase in bed net ownership and correct use (Stromberg et al., 2011).

The above studies illustrate the strength of community health worker projects in increasing community knowledge of malaria, providing malaria medication, and providing education on malaria prevention. However, they also emphasize the need for comprehensive training for community health workers to be effective. This necessitates that community health worker projects are either narrow in scope to be able to provide training on all project aspects, or that projects incorporate continuous training to ensure that participants have training on a wider range of issues.

**Mosquito Control and Surveillance**

While many malaria projects focus on disease management, such as medication and bed nets, malaria management can also be accomplished through vector control. Community health worker based vector control can be used to not only manage malaria, but a variety of other vector borne disease such as dengue or Zika. Mosquito control and surveillance consists of three main components: adult mosquito surveillance, larval mosquito surveillance, and larval control. Most community health worker projects either focus on the larval or the adult aspect of surveillance and control, and have focused on controlling
Ae. aegypti, a vector for yellow fever and dengue, or on the various Anopheles vectors of the Plasmodium parasites that cause malaria. Each mosquito has a unique biology and habitat and as such project planners must decide which mosquito species the project will target or train community health workers to address specific environments that may harbor multiple species; i.e. Culex quinquefasciatus and Ae. aegypti both dominate the peridomestic environment and can be simultaneously surveyed.

Most of the community health worker projects targeting malaria transmitting mosquitoes have taken place in Africa, especially Eastern Africa. A project on Rusinga Island in western Kenya was created with the goal of fostering a relationship between academic partners and local community workers to create more effective mosquito control strategies. The partnership was between the University of Nairobi Department of Zoology, the Rusinga Island Child and Family Programme of the Christian Children’s Fund, and volunteers from the local community. Initial organization and mobilization was facilitated by the Rusinga Island Child and Family programme, and began as shareholder meetings between academic partners and the local community to recruit volunteers to establish an active malaria surveillance and control program on the island. While the island already had a group trying to provide malaria control through mosquito control their information was outdated, and many volunteers were unable to identify mosquito larva or their habitats. A training course involving demonstrations of mosquito life cycle and habitat resulted in more than 70 volunteers being able to identify Anopheles mosquito larva and mosquito habitat (Mukabana et al., 2006). Despite the lack of follow-up information to measure the effectiveness mosquito control resulting from this project, it demonstrated the benefits of partnerships between community health organizations and academic partners to provide quality information and resources to support community-based initiatives.

Potential cost reduction is another benefit of community health worker-based mosquito surveillance. A project in Zambia looked at using community health workers to deploy both light traps and Ifakara Tent Traps to collect adult mosquitoes. Community health workers sorted adult mosquitoes collected by eye to genus level, and Anopheles mosquitoes were sent to the lab for further testing. The results from these collections were compared to both quality assurance trapping surveys and a
longitudinal malaria survey of residents. Overall, the community-based trapping project exhibited lower capture rates of adult mosquitoes compared to the quality assurance trapping. However, the community trapping numbers showed a strong correlation with local malaria incidence showing the epidemiological relevance of the project. The community-based trapping was also significantly cheaper than the quality assurance trapping. The quality assurance trapping cost $141.20 US dollars per specimen for light traps and $168.20 US dollars per specimen for Ifakara Tent Traps, while the community trapping cost $5.30 US dollars per specimen for light traps and $28.00 for Ifakara Tent Traps. This cost savings and the trappings epidemiological relevance offset the lower trap counts and made this an effective trapping scheme (Sikaala et al., 2014).

The other major mosquito vector targeted by community-based projects is the *Ae. aegypti* mosquito. The container breeding habits of the species have made it a prime target for both larval surveillance projects and projects attempting local eradication. From 2000 to 2003 a project was run in Central Vietnam attempting local eradication of *Ae. aegypti* through use of predacious copepods. Community management committees were set up in three rural communes selected for the project and were tasked with recruiting local collaborators to perform monthly household larval inspections and to distribute copepods for larval control. Provincial level health staff were provided training on mosquito control and surveillance and provided trainings for local committees and volunteers. Volunteers were trained to distinguish between *Aedes* and *Anopheles* larva, and to distinguish them from the various copepods and other organisms in the water. Volunteers were given mosquito control manuals and recorded their activities to report back to the committee. Control methods included introducing copepods into containers over 100 liters and cleaning up trash and other potential breeding sites. Twelve entomological survey were conducted to establish the effectiveness of the control, and disease surveillance was also conducted. The surveys indicated that the larval population was reduced by 90% after one year of intervention and showed a similar drop in adult density. There was a 76.7% reduction in dengue incidence after the first year of the project, and zero cases recorded in the projects final two years (Vu et al., 2005). Community larval projects in Guantanamo, Cuba and Guatemala using household
surveys and control using various methods showed similar reductions in larval incidences after intervention (Ulibarri et al., 2016; Vanlerberghe et al., 2009).

Discussion

Community health worker programs have been successfully engaged across a wide variety of health fields, from environmental health to mosquito surveillance. One of the main benefits of community health worker programs is low cost and ability to integrate into communities. Community-based mosquito surveillance schemes can cost $136 to $140 dollars less per trap than traditional surveillance methods (Sikaala et al., 2014). The invasive natures of certain health interventions, such as mosquito trapping or home inspections, require a large amount of cultural sensitivity and community trust. Many communities that these interventions target have histories of white oppression and exploitation by the traditional medical establishment. Community health workers, due to their investment and understanding of the communities they are involved with, have a unique ability to act as a bridge between various health resources and their communities (Abrahams-Gessel et al., 2015).

Most mosquito surveillance projects discussed in this literature review were novel programs. Their projects focused on recruiting new volunteers or community members, instead of having preexisting community health organizations incorporate a project into existing tasks. The main benefit of creating a novel program is that it allows a large amount of community involvement in program set up. Several novel mosquito surveillance programs started by having community members choose the health workers for the program in their village (Stromberg et al., 2011; Yasuoka et al., 2010). This involvement can promote feelings of ownership and investment within the community and promote community interest in the program. Community support is critical for facilitating trust in the community health workers and ultimately project success. Creating a novel program can also ensure that community health workers do not have other tasks that may interfere with performing project duties. Unrealistic workloads have been found to have detrimental effects on project success (S. Abrahams-Gessel et al., 2015). Creating a novel program allows workload to be controlled by the organizers, with minimal interference from other tasks.
Some of the main challenges with creating a novel community health worker program are funding and integration into existing healthcare systems. Studies conducted on community health worker effectiveness in screening for cardiovascular disease found that compensation for tasks, and a clear way to communicate with clinical staff were important for project success (Abrahams-Gessel et al., 2016; Abrahams-Gessel et al., 2015). Ensuring proper funding for a project falls on the organizer of a project, as well as developing a plan for connecting and integrating a project into the local healthcare system. Creating a project with government or clinical support can help mitigate some of these issues and facilitate program success.

Another strategy for using community health workers in mosquito surveillance is through add-on programs. This involves incorporating mosquito surveillance into pre-existing tasks of a community health worker organization. Health worker organizations that focus on home inspections and environmental health are likely the most suited for mosquito surveillance project. Partnering with an existing community health worker program also allows the project to take advantage of the trust that program has already built within the community. It can potentially be less expensive than creating a novel program as well, as the project does not represent a sole source of income and can be incorporated with funding already present for the organization. The major drawback of add-on programs is that they require balancing project tasks with other tasks already expected of community health workers. Overwork can be a major factor in project failure, and must be considered when creating an add-on program (S. Abrahams-Gessel et al., 2015).

Arizona already has several community health worker organizations, including those organized under the Arizona Community Health Workers Association. The number of preexisting community health worker organizations in Arizona, including ones involved in environmental health concerns such as the Sonoran Environmental Research Institute (SERI), make Arizona an ideal location to trial add-on projects for mosquito surveillance and control. Community health workers already hold positions of trust within Arizonan communities, which is important due to the invasive nature of mosquito surveillance. Add-on community health worker surveillance projects also have the potential to supplement other mosquito
surveillance done by public health departments, giving more complete mosquito surveillance statewide, and helping prepare for potential mosquito-borne disease outbreaks.

Conclusions

Community health workers have been successfully engaged in mosquito control and surveillance across the world but have rarely been used in this role in the United States. A novel community health worker mosquito surveillance program requires a large amount of funding and organization, which can be circumvented by using surveillance as an add-on project for existing community health worker programs. Arizona has a strong community health worker presence and is an ideal environment to test an add-on surveillance program.
Chapter 2-Engaging Community Health Workers in Larval Mosquito Surveillance in Arizona

Introduction

Vector-borne disease accounts for 17% of all global infectious disease cases (World Health Organization, 2017). The *Aedes aegypti* mosquito is a major contributor to vector-borne disease as a key vector for the viruses causing Zika, chikungunya, dengue, and yellow fever. More than 3.9 billion people globally are at risk from dengue alone (World Health Organization, 2017). While *Ae. aegypti* originated in the wet and tropical environment of sub-Saharan Africa, it has since achieved a worldwide distribution (Kamal et al., 2018; Powell & Tabachnick, 2013), including urban areas of the Sonoran Desert in both Mexico and the United States. *Ae. aegypti* appeared locally extinct in Tucson, Arizona in 1946, but were found to have reinvaded in the early 1990s (Engelthaler et al., 1997). The Great Arizona Mosquito Hunt, a citizen science project run from 2015-2017, found evidence of *Ae. aegypti* presence in seven different Arizona counties (Tarter et al., 2019). While there is no evidence of local arboviral transmission by this vector in Arizona. However, in 2014 a binational dengue outbreak along the Arizona-Sonora border resulted in 93 travel related cases in Arizona (Jones et al., 2016). In 2018 there were five confirmed travel-associated cases of dengue (Arizona Department of Health Services, 2019a), and two confirmed travel-associated cases of Zika (Arizona Department of Health Services, 2019b). In the neighboring Mexican state of Sonora there were 27 confirmed cases and 982 probable cases of dengue in the neighboring Mexican state of Sonora (Border Infectious Disease Surveillance Program, 2018) in 2018 as well as 347 cases of Zika (Border Infectious Disease Surveillance Program, 2019).

Accurate knowledge of *Ae. aegypti* distribution is needed to effectively inform vector control strategies. The cryptic breeding habits of *Ae. aegypti* also necessitate large numbers of personnel to conduct larval inspections and larval control measures. One possible solution is to engage the public through citizen science initiatives to aid in mosquito surveillance, which was done successfully by the Great Arizona Mosquito Hunt, by recruiting high school teachers and students to place and monitor ovitraps for *Ae. aegypti* eggs (Tarter et al., 2019). Another possible solution is recruiting community health workers for mosquito surveillance. Community health worker mosquito surveillance and control
programs have been launched successfully in eastern Africa, southeast Asia, and Latin America (Mukabana et al., 2006; Sikaala et al., 2014; Ulibarri et al., 2016; Vanlerberghe et al., 2009; Vu et al., 2005). The main advantage of using community health workers is their close relationship to their communities, making them uniquely situated to conduct invasive tasks, such as searching homes and properties for mosquito larva. Community health workers could help provide key information on *Ae. aegypti* larval habitat and distribution in Arizona, as well as provide community education on mosquito-borne disease and prevention.

This project was conceived with the intent to test the feasibility of incorporating mosquito larval surveillance programs into preexisting community health worker organizations in the Arizona-Sonora area. The goals of this project were to:

1) Analyze if didactic techniques were effective for educating community health workers about mosquito-borne disease and surveillance.

2) Determine if community health workers could provide effective larval surveillance and community outreach.

3) Determine if larval surveillance conflicted with other organization responsibilities.

4) Determine if community health workers felt that mosquito surveillance was important and fit into their public health worker role.

**Methods**

The project was conducted over two mosquito seasons, July to October, with a pilot season in 2018 and follow-up season 2019. We worked with two organizations, one in Tucson, AZ and one in Yuma, AZ. Both areas have established *Ae. aegypti* populations, and Yuma has experienced a travel-related dengue outbreak (Engelthaler et al., 1997, Tarter et al., 2019, Jones et al., 2016). The Tucson organization was the Sonoran Environmental Research Institute (SERI) a community health worker organization focusing on environmental health issues. SERI participated in both the 2018 pilot and 2019 project seasons and sought to incorporate larval surveillance into environmental home inspections already conducted by the organization. The Regional Center for Border Health in Yuma joined the project for the
2019 season. This organization is primarily concerned with community health education and outreach and was interested in incorporating larval mosquito surveillance into these goals.

The larval surveillance training for community health workers consisted of two parts. Part one was a didactic classroom training model made up of a presentation on mosquito biology, habitat, disease transmission and mosquito control. Part two of the training was a field training on larval surveillance, involving conducting surveillance at a determined location with larvae hidden in spots for participants to find. This training included different tools for larval surveillance and how to use them. A pre-survey was administered before the classroom training to establish the base level knowledge of participants, and a post survey was done after the classroom training to quantify participant knowledge gains from the training. Pre- and post-surveys included three statements to determine if participants viewed mosquito-borne disease as a threat in Arizona, if they thought mosquito-borne disease affected the communities they worked in, and if they thought mosquito surveillance fit into their jobs as community health workers. Participants were asked to indicate how strongly they agreed with each statement on a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). A paired t-test was used to analyze the difference between pre- and post-survey scores.

After the training, community health workers were to conduct larval surveillance at houses in their community and send collected samples to the University of Arizona for identification by the research team. During the 2018 pilot season with SERI, paper forms were provided for community health workers to complete during inspections. The forms served as a task checklist for health workers to complete while visiting homes and properties. Tasks included counting the number of potential breeding sites with water, collecting larval samples, and asking homeowners what mosquito prevention activities they engaged in. Feedback from SERI indicated that the paper system was cumbersome, and they developed a tablet-based system for their own use during the 2019 season. Based on this feedback it was left to organizations to decide on their own system of recording samples and gathering information about homeowner mosquito prevention for the 2019 season.
Results

2018 season

During the 2018 season with SERI, pre- and post-surveys were not distributed during the didactic training. Feedback on how to improve the training materials was gathered with SERI during a post season focus group. Community health workers indicated that they wanted more information on disease and disease symptoms than had been provided in training. The hands-on mosquito surveillance demonstration was well received, as it provided practical skills, and gave a more complete idea of the mosquito breeding sites and larval stages. Over the course of the mosquito season, seven larval samples were received, six of which contained mosquito larva. The seventh sample was an aquatic fly larva. The overall conclusion for the season was that the project showed promise and should be expanded to other community health worker groups in the 2019 season.

2019 season

During the 2019 season 17 community health workers from SERI and the Regional Center for Border Health participated in the project. Pre- and post- surveys were used to determine the effectiveness of the didactic classroom training model. The surveys were graded out of 47 points and compared using a paired t-test (Figure 1). On average participant scores increased by 4.88 points, and the t-test
indicated significant differences between pre- and post-survey scores, ($p < 0.001$, using an alpha level of 0.05. Four questions specifically showed improvement pre and post, when compared using a paired t-test (Figures 2-4). These were questions on what types of mosquitoes transmitted each disease ($p = 0.00005$), what age group is most at risk for West Nile virus ($p = 0.0047$), which virus caused microcephaly ($p = 0.0072$), and how to control mosquito breeding ($p = 0.015$). No mosquito larval samples were collected during the 2019 season.

On the pre-survey 88% of study participants indicated that they either agreed or strongly agreed that mosquito-borne disease is a threat in Arizona and that mosquito surveillance fits within their role as a community health worker. Similarly, 82% of participants on the pre-survey indicated that they either agreed or strongly agreed that mosquito-borne disease affected the communities they work in. On the post-survey 100% of participants agreed or strongly agreed with these statements.

**Discussion**

This study provides evidence that a didactic training model combined with hands-on training is an effective way to educate community health workers about mosquito-borne disease and surveillance. Analysis of training participant pre- and post-survey scores showed a significant increase in knowledge about mosquito-borne disease. During the hands-on larval surveillance training, community health
workers successfully identified larval habitats and collected larval samples, including finding habitats and larva the instructor missed. The samples sent during the 2018 season also indicated that community health workers can successfully conduct mosquito larval surveillance given proper training.

While the didactic training was effective overall, it was not particularly effective at teaching specific disease symptoms. The length of the training was insufficient for participants to learn to distinguish between different mosquito-borne diseases. A longer multi-day training may allow participants more time to study and memorize disease symptoms. An online module for the didactic training could be used to make comprehensive trainings more accessible to a wider range of community health workers. Similarly, the didactic classroom training was not particularly effective for helping community health workers identify mosquito larval sites, which highlights the necessity for hands-on larval surveillance training.

The major barrier for engaging community health worker organizations in mosquito surveillance is finding a way to balance the workload for health workers between the project and other required tasks. Feedback from SERI for the 2018 season indicated that using a paper survey and recording system was inefficient, as it required the same amount of time as an entire house inspection. For the 2019 season, SERI streamlined the data collection process by utilizing an electronic version of the survey, via tablets. However, in 2019 the grant SERI had received to conduct home inspections, which included larval inspections, was unavailable and prevented larval samples from being collected. No larval samples or inspections were received from the Regional Center for Border Health in Yuma because mosquito season overlaps with their walk-in clinic. This prevented the Regional Center for Border Health from performing mosquito surveillance.

Community health workers demonstrated a clear grasp of the importance of mosquito-borne disease in Arizona and their communities, and strongly agreed that mosquito surveillance fits within their role as community health workers, as demonstrated by survey answers. While conducting surveillance may not be practical for many groups, the knowledge provided by the training is useful, and was clearly desired by both participating organizations. The communities Arizona health workers interact with are at
risk of travel related mosquito-borne illness, due to proximity and relations with Mexico, as well as locally transmitted mosquito-borne disease. These health workers who perform home inspections and run walk-in clinics are likely to be one of the first public health employees to see patients with mosquito-borne disease symptoms. It is vital that they have the knowledge to recognize these symptoms and take appropriate actions. While engaging community health workers in routine mosquito surveillance faces logistical challenges, providing trainings for community health workers on mosquito and vector-borne disease is beneficial, allowing them to educate the communities they work in and provide an informal surveillance for vector-borne disease.

Conclusions

While community health workers clearly demonstrated an ability to perform mosquito surveillance, logistical issues complicate the practicality of incorporating it into routine mosquito surveillance. Community health workers showed a strong desire to know more about mosquito-borne disease and are uniquely positioned to identify mosquito-borne illness in communities and educate community members on disease prevention. Finding ways to provide training on vector-borne disease for community health workers on the Arizona-Sonora border remains important, even if it does not contribute to general surveillance.
Appendix A: Pre- and Post-Training Surveys

English Survey

Mosquito Larval Surveillance Pre-Survey

1. Have you had trainings or experience with any of the following mosquito borne diseases? Select all that apply.
   a) Dengue
   b) Zika
   c) West Nile Virus
   d) St. Louis Encephalitis

2. Match the mosquito with the disease it transmits. Some mosquitoes transmit more than one disease
   a) Aedes aegypti __Zika
   b) Culex species __Dengue
   c) Anopheles gambiae __West Nile Virus
      __St. Louis Encephalitis

3. Which of the following are potential symptoms of Dengue? Select all that apply.
   a) Fever
   b) Headache
   c) Body aches
   d) Joint pain
   e) Vomiting
   f) Diarrhea
   g) Rash
   h) Tremors
   i) Convulsion
   j) Muscle weakness
   k) Vision loss
   l) Numbness
   m) Eye pain
   n) Bone pain
   o) Bleeding (nose or gums, easy bruising)
   p) Vomiting blood
   q) Abdominal pain
   r) Conjunctivitis (red eyes)

4. Which of the following are potential symptoms of West Nile? Select all that apply.
   a) Fever
   b) Headache
   c) Body aches
   d) Joint pain
   e) Vomiting
   f) Diarrhea
   g) Rash
   h) Tremors
   i) Convulsion
   j) Muscle weakness
   k) Vision loss
   l) Numbness
   m) Eye pain
   n) Bone pain
   o) Bleeding (nose or gums, easy bruising)
   p) Vomiting blood
   q) Abdominal pain
   r) Conjunctivitis (red eyes)

5. Which age group is most at risk for severe West Nile symptoms?
   a) 10-25 years
   b) 25-40 years
   c) 40-60 years
   d) 60 and older

6. Which of the following are potential symptoms of Zika? Select all that apply.
   a) Fever
   b) Headache
   c) Body aches
   d) Joint pain
e) Vomiting
f) Diarrhea
g) Rash
h) Tremors
i) Convulsion
j) Muscle weakness
k) Vision loss
l) Numbness
m) Eye pain
n) Bone pain
o) Bleeding (nose or gums, easy bruising)
p) Vomiting blood
q) Abdominal pain
r) Conjunctivitis (red eyes)
7. Microcephaly (shrunken head) in newborns is a symptom of which virus?
   a) Zika
   b) West Nile
   c) Dengue
   d) Malaria

8. How is Zika transmitted?
   a) By mosquito
   b) Sexually
   c) Through saliva
   d) Both a and b
   e) All of the above

9. It only takes the bite of one infected mosquito to become infected?
   a) True
   b) False

10. Everyone infected will get sick?
    a) True
    b) False

11. Where do mosquitoes breed? Circle all potential breeding sites in this image

12. Which of the following are effective ways to control mosquito breeding? Check all that apply
    a) Remove standing water breeding sites
    b) Treating breeding sites with Bti briquets
c) Hanging pennies in water

13. Which of the following are effective ways to prevent mosquito bites? Check all that apply
   a) Installing window screens
   b) Using mosquito repellent
   c) Using citronella candles
   d) Using essential oils
   e) Wearing long sleeves and pants

Read the following statements and rank how strongly you agree with them on a scale of 1 to 5.

14. Mosquito borne disease is a threat in Arizona
   Strongly disagree  Disagree  Undecided  Agree  Strongly agree
   1 2 3 4 5

15. Mosquito borne disease affects the communities I work in
   Strongly disagree  Disagree  Undecided  Agree  Strongly agree
   1 2 3 4 5

16. Mosquito surveillance fits with my job as a community health worker.
   Strongly disagree  Disagree  Undecided  Agree  Strongly agree
   1 2 3 4 5

Spanish Survey

Encuesta de vigilancia de larvas de mosquitos

17. ¿Ha tenido capacitación o experiencia con alguna de las siguientes enfermedades transmitidas por mosquitos? Seleccione todas las que correspondan.
   a) Dengue
   b) Zika
   c) Vírus del oeste del Nilo
   d) Encefalitis de San Luis

18. Combina el mosquito con la enfermedad que transmite. Algunos mosquitos transmiten más de una enfermedad.
   a) Aedes aegypti  __Zika
   b) Culex especies  __Dengue
   c) Anopheles gambiae  __Vírus del oeste del Nilo
                        __Encefalitis de San Luis

19. ¿Cuáles de los siguientes son síntomas potenciales del dengue? Seleccione todas las que correspondan.
   a) Fiebre
   b) Dolor de cabeza
   c) Dolor de cuerpo
   d) Dolor en las articulaciones
   e) Vomitar
   f) Diarrea
   g) Erupción
   h) Temblores
   i) convulsión
   j) Debilidad muscular
   k) Pérdida de la visión
   l) entumecimiento
   m) Dolor de ojo
   n) Dolor de huesos
20. ¿Cuáles de los siguientes son síntomas potenciales del Nilo Occidental? Seleccione todas las que correspondan.
   a) Fiebre
   b) Dolor de cabeza
   c) Dolor de cuerpo
   d) Dolor en las articulaciones
   e) Vomitar
   f) Diarrea
   g) Erupción
   h) Temblores
   i) convulsión
   j) Debilidad muscular
   k) Pérdida de la visión
   l) entumecimiento
   m) Dolor de ojo
   n) Dolor de huesos
   o) Sangrado (nariz o encías, moretones fáciles)
   p) Vómitos de sangre
   q) Dolor abdominal
   r) Conjuntivitis (ojos rojos)

21. ¿Qué grupo de edad tiene mayor riesgo de presentar síntomas graves del Nilo Occidental?
   a) 10-25 años
   b) 25-40 años
   c) 40-60 años
   d) 60 años y mayores

22. ¿Cuáles de los siguientes son síntomas potenciales de Zika? Seleccione todas las que correspondan.
   a) Fiebre
   b) Dolor de cabeza
   c) Dolor de cuerpo
   d) Dolor en las articulaciones
   e) Vomitar
   f) Diarrea
   g) Erupción
   h) Temblores
   i) convulsión
   j) Debilidad muscular
   k) Pérdida de la visión
   l) entumecimiento
   m) Dolor de ojo
   n) Dolor de huesos
   o) Sangrado (nariz o encías, moretones fáciles)
   p) Vómitos de sangre
   q) Dolor abdominal
   r) Conjuntivitis (ojos rojos)
23. La microcefalia (cabeza contraída) en los recién nacidos es un síntoma de qué virus?
   a) Zika
   b) Nilo Occidental
   c) Dengue
   d) Malaria

24. ¿Cómo se transmite el Zika?
   a) Por mosquito
   b) Sexualmente
   c) A través de la saliva
   d) Tanto a como b
   e) Todas las anteriores

25. ¿Solo toma la picadura de un mosquito infectado para infectarse?
   a) Cierto
   b) Falso

26. ¿Todos los infectados se enfermarán?
   a) Cierto
   b) Falso

27. ¿Dónde se reproducen los mosquitos? Encierra en un círculo todos los sitios potenciales de reproducción en esta imagen
28. ¿Cuáles de las siguientes son formas efectivas de controlar la reproducción de mosquitos? Marque todo lo que corresponda.
   a) Eliminar los criaderos de agua estancada
   b) Tratamiento de criaderos con briquetas de Bti.
   c) Colgar centavos en el agua.

29. ¿Cuáles de las siguientes son formas efectivas de prevenir las picaduras de mosquitos? Marque todo lo que corresponda.
   a) Instalación de pantallas de ventana
   b) Usar repelente de mosquitos
   c) Utilizando velas de citronela
   d) Usar aceites esenciales
   e) Usar mangas largas y pantalones

Lee las siguientes afirmaciones y clasifica en qué medida estás de acuerdo con ellas en una escala de 1 a 5.

30. La enfermedad transmitida por mosquitos es una amenaza en Arizona
    Muy en desacuerdo discrepar indecido De acuerdo Totalmente de acuerdo
    1 2 3 4 5

31. Las enfermedades transmitidas por mosquitos afectan a las comunidades en las que trabajo
    Muy en desacuerdo discrepar indecido De acuerdo Totalmente de acuerdo
    1 2 3 4 5

32. La vigilancia de mosquitos encaja con mi trabajo como trabajador comunitario de salud.
    Muy en desacuerdo discrepar indecido De acuerdo Totalmente de acuerdo
    1 2 3 4 5
### Appendix B: Raw Scoring for Pre- and Post-Surveys

#### Table 1. Pre-didactic training survey scores

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</tr>
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<td>16</td>
<td>4</td>
<td>5</td>
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<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>31</td>
</tr>
</tbody>
</table>

Average 2.59 3.82 3.53 0.94 2.06 0.82 0.18 0.94 0.82 4.00 1.71 2.88 24.29
Appendix C: Paper Based Mosquito Surveillance Survey

MOSQUITO SURVEILLANCE CHECKLIST

HOUSEHOLD ID #:

NAME:

DATE:

TIME OF DAY:

PROPERTY ADDRESS:

☐ TUCSON  ☐ NOGALES

Statement of Informed Consent

Hello, my name is ___________. I am working with the University of Arizona on a research project about involving community health workers in mosquito surveillance. We would like to ask you to participate in this project by allowing us to inspect your home for mosquito larva. Participation in this research study is voluntary, and you can opt out at any time. There is no risk to you, or your family, and any information collected in this study will be confidential, and your survey will be identified by address. Your address will not be published in any reports resulting from this study. Feel free to ask questions before making your decision whether or not to participate.

If you choose to participate in this study a community health worker will inspect your property for mosquito larva and ask you some questions about mosquito activity on your property. There is no cost or compensation for participating. The inspection and survey should take about 30 minutes. After the inspection we will clear your property of mosquito larva and provide you with tips and supplies to deal with future mosquito issues. If you have questions about the project, feel free to contact Josh Arnbrister (phone) or Kacey Ernst (520-626-7374).

Inspectors initials: ___________.

Questions to ask residents before inspection

- Have residents been bitten by mosquitoes within the last week? Yes ☐ No ☐
- Have residents used mosquito repellent in the last week? Yes ☐ No ☐
- Have residents checked property for standing water in last two weeks? Yes ☐ No ☐

Things to look for during inspection

- Were you bitten by any mosquitoes during home visit? Yes ☐ No ☐
- Did you observe any adult mosquitoes? Yes ☐ No ☐
- Are there window screens? Yes ☐ No ☐
- Are window screens intact? Yes ☐ No ☐
### Mosquito Breeding Sites (+ mark for present, - mark for absent)

<table>
<thead>
<tr>
<th>Breeding Site</th>
<th>Water</th>
<th>Mosquito Larva</th>
<th>Approximate Container #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tarps</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buckets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flower Pots</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plastic containers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tires</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Harvesting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Feature (bird bath, fountain)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Was the water harvesting basin covered? Yes □ No □
- If water feature present is it they regularly maintained? Yes □ No □

### Follow-up measures after inspection

- Talked with home owner about mosquitoes Yes □ No □
- Left brochures? Yes □ No □
- Informed them about Kidenga as a resource Yes □ No □
- Provided mosquito dunks? Yes □ No □
- Did you take samples? Yes □ No □
- How many samples were taken?
References


Border Infectious Disease Surveillance Program (2019). *Zika Virus Location Report, Week 52.*


doi:10.1146/annurev-publhealth-032013-182354


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Vanlerberghe, V., Toledo, M. E., Rodríguez, M., Gomez, D., Baly, A., Benitez, J. R., & Van der Stuyft,
doi:10.1136/bmj.b1959

community programs using Mesocyclops(Copepoda) against Aedes aegypti in central Vietnam.


room/fact-sheets/detail/vector-borne-diseases


Assessing the quality of service of village malaria workers to strengthen community-based