A Comprehensive Needs Assessment to Identify Priority Program Targets for Mosquito Vector Control and Related Diseases in Belmopan, Belize

by

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Thesis submitted in partial fulfillment of
the requirements for the degree of
Master of Science in the Duke Global Health Institute
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ABSTRACT

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Abstract

This was a mixed-methods study aimed to comprehensively assess factors associated with mosquito control in Belmopan, Belize, in order to better inform stakeholders on the effectiveness of their efforts. A knowledge, attitudes, and perceptions (KAP) survey was employed within the four target communities of San Martin, Salvapan, Maya Mopan, and Las Flores. Additional epidemiological and entomological data was provided by relevant stakeholders. A total of 228 households were surveyed among the four target communities. Only 1/3 of respondents were able to demonstrate proficient knowledge. Knowledge was attained mostly through TV, Ministry of Health, hospital, and radio sources. Over 90% of respondents believed that mosquitos and the diseases they carry were a real issue for the community. Respondents living in Salvapan and Las Flores were more likely to have contracted Dengue Fever, Malaria, Chikungunya, or Zika than in other areas. Fan usage and regularly cleaning the yard were the two most employed practices for preventing mosquito bites and breeding. Approximately 85% of those surveyed viewed insecticide spraying to be effective. This assessment provides valuable insight into the needs of at- risk communities in regards to vector control. An increased focus on community outreach, education, and behavioral change can greatly impact the effectiveness of current vector control efforts. Stakeholders must work together and pool resources in order to effectively employ control interventions. Continued evaluation and community involvement is necessary to control mosquitos and prevent disease outbreaks.

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Acknowledgments

This research was supported by Duke Kunshan University and the Duke Global Health Research Institute. I would like to thank my supervisors Dr. Alba Amya-Burns and Dr. Allan Burns for their support, feedback and encouragement throughout my studies and project. Without them this research would never have occurred.

I would also like to thank and recognize my field supervisor Dr. Pio Saqui for all of his assistance. He not only provided a warm welcome to Belize and provided much needed research support, but also ensured that I had a roof over my head, good food to eat, and plenty of mental relaxation. The project would not have been a success without him and his family.

I would like to show my gratitude to my research team Hector Cucul, Maria Pech, Melissa Chiac, and Saul Osorio for their hard work and positive attitudes. I am also immensely grateful to Mr. Kim Bautista, Mr. Javier Alpuche, Eugene Lisbey, and Hans Gutierrez for their support and assistance throughout the project. I would especially like to thank Rolando Cocom with the Institute of Social and Cultural Research who helped the project receive approval. An extended thank you goes out to the stakeholders Phillip Timmons, Dr. Castillo, Dr. Cheron, Dr. Salazar, the Ministry of Health Epidemiological Unit and the University of Belize who were also a very important and supportive group.

1. Introduction

1.1 Vector-borne Diseases Worldwide

According to the World Health Organization (WHO) vector borne diseases contribute to 17% of infectious diseases worldwide and are found to be the cause of one million deaths a year (WHO, 2016). As a contributor to this burden, mosquitos from the family *Aedes* are major targets of vector control efforts around the world. One of the most infamous vectors to carry these deadly infectious diseases are the mosquitos from the family *Aede*s. Mosquitos from the *Aedes* family can carry dengue fever, chikungunya, zika, mayaro, as well as West Nile and Yellow Fever (Mosquito Control, 2016). The viruses that the Aedes mosquitos carry are very similar, difficult to diagnose, and range in their impact on human health. These diseases also create a large burden on the communities effected, as well as on the individuals who contract the diseases.

The worldwide financial costs of *Aedes* related diseases are high. Dengue Fever, for example, has cost the world $39 billion USD which includes loss of productivity, prevention measures, and medical costs (Sanyaolu *et al.*, 2016). During the 2006 epidemic of chikungunya in India, the estimated financial burden caused by the loss of employees to illness was $6 million USD (Sanyaolu *et al.*, 2016). Zika and mayaro viruses are expected to follow the same costly pattern. This burden on communities worldwide is predicted to increase as immigration, tourism, and trade continue to areas endemic with these diseases (Campbell-Lendrum *et. al.*, 2015). In fact, the U.S. has already reported 4,650 travel-based cases of Zika in almost every state while Florida and Texas have reported 216 local cases

(Maps of Zika, 2017). It has also been documented that the *Aedes albopictus* mosquito, a carrier of the diseases, was brought to the Americas via the tire trade in 1985 (Paupy *et. al*., 2009). This demonstrates that the increase of immigration, tourism, and trade has played an important role in spreading the diseases that *Aedes* mosquitos carry from endemic areas to non-endemic ones.

The *Anopheles* mosquito is another major contributor to infectious disease burdens worldwide. As the vector for the malaria parasite, it has been a primary target for vector control and medical efforts for many years. Malaria has been a major factor in under-five mortality and in 2015 a total of 212 million cases of Malaria were reported worldwide (WHO, 2017). Despite this the child mortality rate has been reduced by 29% and the incidence rate has been reduced by 21% globally between 2010 and 2015 (WHO, 2017). Due to economic and time constraints, this study's primarily focuses on *Aedes* mosquitos and their related diseases; however, some malaria related information was still collected as it is a relevant contributor to disease burden.

1.2 Burden of Vector-borne Diseases

There are increased financial and economic burdens on the well-being of individuals and the health systems. Studies were conducted in 2005 in eight countries, five in the Americas and three in Asia. These studies concluded that for each case of dengue the episode would last approximately 11 days depending on if the patient was hospitalized or not. During this time, if the patient was hospitalized, they would lose on average 5.6 days of school and 9.9 days of work (Suaya et. al., 2009). In the academic world five days missed of school is difficult to make up and can permanently impact grades. Also, missing almost ten days of work can hurt one's income if they are living paycheck to paycheck as well as put into question their job security. There is also a long-term impact that these diseases can inflict on an individual's well-being. For example, in the 2006 epidemic of chikungunya in India long-term symptoms caused a burden of 45.26 DALYs per million people (Sanyaolu *et al.,* 2016).

Treatment for these diseases also imposes an economic burden. The average cost for an episode of dengue was $514 USD for ambulatory services and $1491 USD for hospital services (Campbell-Lendrum *et. al.,* 2015). This is especially a high amount when most people who contract dengue are living in poorer economic and social conditions. This in turn puts more financial burden on the health systems. Health systems in developing countries are especially overwhelmed as cases of vector-borne diseases are approximately 300 times greater in their regions due to climate and poor health services and measures (Campbell-Lendrum *et. al.,* 2015).

Not only do these diseases cause burden to the communities they affect, but external factors can increase or even counteract the spread and severity of these burdens. These factors include deforestation, rapid urbanization, political unrest, climate change, and socioeconomic development. Deforestation has been found to lead to the creation of breeding sites for mosquitos that carry malaria. It has also increased the rate in which humans come into contact with zoophilic vector species, like the *A. albopictus* (Walsh *et. al.,*2011; Paupy *et.al.,* 2009). This has led to humans becoming a new source of food for the vectors, therefore, increasing or introducing new patterns of disease (Walsh *et. al.*,2011). Rapid urbanization will then occur in deforested areas as new land becomes available. Urbanization contributes to the reduction of *Anopheles* breeding sites and the increase of *Aedes* breeding sites (Campbell-Lendrum *et. al.*, 2015). This makes urban areas more likely to be potential grounds for dengue epidemics. Political unrest contributes to the spread of these diseases in a similar way to deforestation and urbanization. Migration through underdeveloped areas and environmental destruction leads to the creation of breeding sites and increased contact with the vectors. Also, overcrowding and poor water and shelter conditions will lead to increased spread of disease and new breeding sites (Beyrer *et. al*., 2011). There is also a reduction of vector control programs and health infrastructure; however, this does not have to be during a time of political unrest but can be due to political corruption or economic burden.

Finally, scientists have found that climate change and socioeconomic development can act for or against vector-borne disease spread and incidence. For example, in areas where rainfall and temperatures are increasing, these environments are becoming more suitable for mosquitos and other vectors whereas areas experiencing droughts are becoming less suitable. More specifically, climate change models are predicting that malaria and dengue burdens will be higher than they have been. If we can predict and adapt to these changes then the disease burdens may not be as impactful (Campbell-Lendrum *et. al.*, 2015; Caminade *et al*., 2014). Scientists have also found that socioeconomic factors are having a larger impact on dengue burden than climatic factors. One study suggested that if climate change predictions occur exactly as predicted with no change in the gross domestic product per capita or GDPpc (measurement of socioeconomic development) then the population at risk of dengue will increase by 280 million people. However, if the GDPpc is to increase, as predicted, in conjunction with climate change then the population at risk of dengue transmission will actually decrease by 120 million (Åström *et al*., 2012). This demonstrates that, although climate change does affect disease transmission, socioeconomic factors also play a large role.

Vector-borne diseases, especially those carried by mosquitos, present what is known as a "wicked" problem (Churchman, 1967). The conglomerate of factors that contribute to the incidence and burden of disease are complex and are likely impossible to solve or eradicate. However, attempts should be made to at least reduce and prevent vector-borne disease transmission.

In order to decrease the burden of *Aedes* mosquito diseases, there needs to be a focus on treatment and prevention. Vaccines may not be available or are not yet available in all countries and treatment focuses on palliative care. Therefore, a focus on other forms of prevention is needed in order to help supplement the scarcity of vaccines and the complexity of treatment. The only way to prevent transmission is through protecting oneself from mosquito bites or destroying the vector in all phases of development: egg, larvae, and adult.

1.3 *Aedes aegypti* and *A. albopictus*

Vector control has proven difficult for countries affected by dengue, chikungunya, and Zika due to the adaptable behaviors of *Aedes* mosquitos. As demonstrated by the tire trade in 1985 that brought the *A. albopictus* mosquitos to the USA, it has also been difficult to control their spread across borders (Paupy *et. al*., 2009).

A. aegypti mosquitos have been identified as critical public health threats because they are the primary vector for zika, dengue, chikungunya, yellow fever and other viruses. This aggressive, day-feeding mosquito is known to be an "opportunistic," "container breeder," "sip feeder" that utilizes "sneak attacks" to avoid being killed (Mosquito Control, 2016). It is "opportunistic" because it has adapted to urban environments and has been known to prefer human blood over other mammals. The mosquito is known as a "container breeder" because it has adapted to lay approximately 100 to 200 eggs in any object that contains water (Mosquito Control, 2016). A container as small as a water bottle cap could become a potential breeding site. The mosquito is mostly found inside homes because it prefers clean water rather than dirty. Female mosquitos like to take their blood meal in increments, feeding on multiple humans. Thus, they are labeled a "sip feeder" (Mosquito Control, 2016). This causes an increase in the likelihood of disease transmission because one female encounters multiple people in her lifetime. Finally, the female has adapted to attack ankles and elbows. These "sneak attacks" allow her to avoid detection.

A. albopictus mosquitos are quite similar to their *A. aegpyti* cousins, but have some unique adaptions of their own. The *A. albopictus* mosquito has been able to spread to northern environments, unlike its cousin, due to its ability to withstand and survive colder environments (Paupy *et.al*., 2009). It also has a zoophilic feeding behavior, meaning it prefers to feed upon animals rather than humans. This makes the mosquito less likely to instigate human-to-human transmission of viruses. However, it is more likely to cause the introduction of new zoonotic diseases into human populations. *A. albopictus* is not as extreme of a public health threat as *A. aegypti* because they have only been confirmed to actively spread dengue and chikungunya (Paupy *et. al*., 2009).

1.4 History of Prevention strategies

The combination of mosquito biology and behavior and the factors that contribute to the spread and incidence of disease increase the need for community centered interventions. Major challenges that vector control faces is community involvement, adapting to the changing environment and the transitions from rural to urban living, being able to financially support interventions, and having government support. This study addresses these gaps by studying what are the needs of the community as far as vector control is concerned and how these needs can be addressed in an economical, community-based, and adaptable way. However, to do this the researchers first needed to be aware of past efforts to address this “wicked” problem.

One of the first and most effective community programs in destroying mosquito vectors was during the United States construction of the Panama Canal in the early 1900s. The mosquito eradication program had a strong head of command through the Isthmian

Canal Commission (ICC) whose major duty was to eradicate mosquitos and reduce incidence of yellow fever and malaria in the area (Panama Canal, 2015).

The ICC did this by first carefully planning and then focusing their mosquito eradication efforts. The first step was to assess the high-risk areas and identify the main site for mosquito breeding. The ICC then moved forward to begin targeting the mosquitos at the larval stage. They drained all pools within so many feet of the villages and constructed ditches that ensured proper drainage. These ditches were inspected on occasion to ensure continued function and quality (Panama Canal, 2015). The group then targeted large brush areas to be cleared because they believed mosquitos could not cross large open fields (Panama Canal, 2015). When drainage and clearing were not applicable, the workers would put oil or larvicides in bodies of standing water to prevent larval growth (Panama Canal, 2015). This created a thin film on the water's surface that would suffocate the larvae. Antimalarial drugs were also provided to all workers and dispensed in every living quarter. All buildings that were part of the government as well as government housing were screened against adult mosquitos, because this had been effective in other areas (Panama Canal, 2015). In addition, the Public Health Service (PHS) officers were employed to destroy adult mosquitos in houses and tents which was extremely cheap (Panama Canal, 2015). They were also put in charge of implementing sanitary education and other sanitary interventions in hospitals and villages. The PHS officers were treated as equals in the intervention process, giving them a stronger desire to assist in the efforts (Stem, 2005). The interventions reduced the death rates of malaria in workers from approximately 10 per 1000 to 1 per 1000, in just 3 years (Stem, 2005).

The Panama Canal interventions are an example of effective community mobilization to eradicate mosquitos and improve the overall sanitation and health of the community. In fact, many of the issues that the ICC identified are still being targeted in at-risk areas. Eradication programs eventually became heavily reliant on insecticides, which were introduced in the 1940s, because they were highly effective in killing mosquitos (Mosquito Control, 2016). By the 1960s, the mosquito populations were greatly reduced and were no longer seen as a public health threat (Fredericks and Fernandez-Sesma, 2014). Eradication programs were not sustained, resources diminished, and the capacity to combat the mosquito reduced.

Twenty years later in the 1980s, insecticides were no longer as efficient, DDT was banned, and the mosquito vectors and diseases they carried resurfaced. This was partially due to lack of vigilance. However, other factors such as climate change, trade, tourism, and environmental destruction contributed as well (Campbell-Lendrum *et. al.*, 2015; Beyrer *et. al.*, 2011; Paupy *et. al.*, 2009). For example, in 1981 the first dengue hemorrhagic epidemic occurred in the Americas in Cuba and since then the hemorrhagic presentation has continued throughout the Americas. Cuba received approximately 344,000 cases and approximately 10,000 were hemorrhagic. One hundred fifty-eight persons died (Kouri *et al.*, 1998). In four months, Cuban officials controlled the epidemic as they recognized the importance of the community in spreading the disease and were quick to enact community participation in surveillance of the disease (Guzmán, 2012). As a result of this program, Cuba was dengue-free for approximately 16 years; however, dengue returned due to a failure of government intervention (Gubler, 2005). The experience of Cuba in reducing dengue incidence in the 1980s and beyond suggests that community mobilization is the single most effective way of halting the spread of vector-borne diseases and reliance on insecticides should be reevaluated (Spiegel *et al*., 2005).

The increase in *Aedes* populations and increasing epidemics involving the diseases they carry have brought renewed attention to the mosquito's eradication. Also, an increase in temperatures due to climate change have caused the mosquito to migrate to areas where it was once unknown (Butterworth et al., 2016).

The routine, as of present, is to spray cities with insecticides and treat breeding sites with larvicides (Sommerfeld and Kroeger, 2015). However, chemical resistance has been reported for many insecticides and larvicides rendering them ineffective (Morrison et al., 2008; Grisales et al., 2013). High resistance to Temephos larvicides has been reported from 1985 to present day, and resistance can occur after only 13 generations when there is high selective pressure (Wirth and Georghiou, 1999; Bellinato *et.al*., 2016; Goindin *et.al*., 2017). It is also believed that resistant populations will more likely occur when this chemical is available on the retail market (Bellinato *et.al*., 2016). Delatamethrin is used to combat adult populations and has been reported to create highly resistant populations due to constant use and selective pressure (Rodríguez *et.al.,* 2002; Alvarez *et.al.,* 2013; Ngoagouni *et.al.,* 2016; Goindin *et.al*., 2017; Vazquez-Prokopec *et.al.,* 2017). Many studies have also found that mosquito populations had a cross-resistance to Temephos when used in conjunction with Delatamethrin (Wirth and Georghiou, 1999; Alvarez *et.al.*, 2013; Ngoagouni *et.al.*, 2016; Goindin *et.al*., 2017). Malathion generally had low resistance among mosquito populations and had little to no cross-resistance with Temephos (Rodríguez *et.al.*, 2002; Alvarez *et.al.*, 2013; Goindin *et.al*., 2017). This could be explained in some studies because malathion was not consistently used and alternated periodically with Delatamethrin (Goindin *et.al*., 2017). Methoprene larvicides had low resistance when it replaced Temephos, but when these two larvicides were used simultaneously, a high resistance occurred (Braga *et.al.*, 2005; Silva and Mendes, 2007). Methoprene and chemicals like it have generally been more effective in halting the mosquito life cycle than other chemicals used in the past (Silva and Mendes, 2007). Spinosad larvicides are known for their low toxicity levels, which makes it environmentally favorable. Spinosad is highly successful on populations with resistance to multiple other chemicals (Darriet *et.al.*, 2005). Most papers found that resistance can be attributed to point mutations in mosquito DNA or certain metabolic processes (Wirth and Georghiou, 1999; Alvarez *et.al.*, 2013; Ngoagouni *et.al.*, 2016; Moyes *et.al.*, 2017). When resistance is related to point mutations in the population, then this will likely render the chemical useless after so many years (Goindin *et.al*., 2017).

Other methods have been explored that would replace chemical use. Using *Bacillus thuringiensis israelensis* (Bti), a bacterial larvicide, has been effective in reducing dengue incidence where Temephos resistant mosquito populations flourish (Setha *et.al.*, 2016).

Scientists have been attempting to release genetically modified male mosquitos or bacteria-infected males that would mate with females but produce no larvae (Morrison et al., 2008). This may prove to be effective; however, scientists are unable to predict what impact it may have on the environment. More environmentally friendly ways to combat the mosquito have also been explored, such as using guppies and crustaceans in water storage containers as natural predators of the mosquito (Sommerfeld and Kroeger, 2015). Community centered strategies to control mosquito populations are also utilized, yet these programs lack adherence and regulation (Morrison et al., 2008).

Analysis of the history of vector control and current techniques demonstrates a historical pattern. Diseases emerge causing a vector to be identified. Efforts are taken to eradicate said vector. These prove to be effective for a time, but are not sustained, or the vector adapts, rendering efforts unsuccessful. There are also patterns of "herd immunity" which causes disease incidence to be reduced and can also contribute to the reduction of vector control efforts. This is occurring for the zika virus (Groopman, 2017). What is needed is sustainable and adaptable control programs to be put in place that target the needs and issues of the communities affected. Then there would be a higher potential for mosquito populations and disease burdens to be reduced. There are many programs and methods to control mosquito populations. Some are more effective than others but sometimes they can be harmful to the environment. Also, these programs are usually only used when an epidemic occurs and periodically to demonstrate that the government is taking action (Morrison et al., 2008; Mosquito control, 2016).

1.5 Vectors and Disease in Belize

The people of Belize are experiencing a vector control problem in regards to dengue, zika, chikungunya, and other related diseases. A small Central American country of less than 400,000 residents, Belize is a high-risk nation for major infectious diseases (World Fact Book: Belize, 2017). As a country whose economy is strongly based in tourism and foreign investment, outbreaks of infectious diseases can be detrimental to their economy (World Fact Book: Belize, 2017). This also means that Belize could be a key contributor to the spread of vectors and their diseases to non-endemic countries.

Belize has confirmed the presence of both *A. aegypti* and *A. albopictus* and has been combating multiple mosquito-borne diseases for years (Alpuche, 2016). The country was once endemic with malaria, another mosquito borne disease, but has been successful in their control efforts, nearly eradicating it from many areas (Wagman *et al*., 2013). In 1997 the MOH had reported 6,012 total cases. Yet, by 2015, this was reduced to only 9 reported cases nationwide (PAHO, 2012; WHO, 2016). Vector control efforts have focused on insecticide and larvicide use, the use of traps, and periodic dispersal of mosquito nets during epidemics (Wagman et al., 2015). Other vector control efforts have focused on education through the use of brochures, posters, and verbal communication discussing the diseases and the mosquitos that carry them (M., 2016). Despite these efforts, Belize has been endemic with dengue since 1978 and experiences a new outbreak every two to three years. They also had an epidemic of chikungunya in 2014 and confirmed cases of zika in 2016.

The government realized the gaps in their own vector control programs and came up with a national strategic plan to combat dengue and chikungunya in 2015. The five-year plan aims to reduce social and economic issues related to the spread of disease (Belize, 2015). The plan strongly focuses on surveillance, management, laboratory and patient care, and partnership with stakeholders. Whether the plan is being implemented effectively has yet to be determined but the efforts are present. Many new studies are being approved and completed that have focused on the effectiveness of spatial repellants and other insecticides and larvicides, which are effective means of control (Choi *et al*., 2016). These are currently in the process of being completed and the results have yet to be published. Also, the University of Notre Dame is working towards meeting the laboratory goals set by the strategic plan.

It is widely accepted that what is lacking in current elimination programs, as well as in Belize, is quality, scientifically sound, community-based interventions like those used when the Panama Canal was being built (Morrison et al., 2008). This gap is what the current study addresses.

1.6 Study Aims

This study was designed to increase the capacity of the Belizean government to implement effective community-based programs that will lead to the control or reduction of mosquito vectors. By doing so, not only will the local populations reduce the burden of disease and increase their overall health, but neighboring countries and countries who provide tourists, workers, and other migrant populations to Belize will have increased protection against disease and may also begin to implement similar community-based programs. This was a comprehensive descriptive study on the context of mosquito control in Belmopan, Belize. Due to economic and time constraints, the research focused primarily on *A. aegypti* and *A. albopictus* control. However, the MOH suggested that the research be expanded to include malaria related information because this was once a prominent vector-borne disease in the area. It is also important to observe the control efforts in a holistic manner as continued prevention of malaria is important, and *Aedes* mosquitos have been known to adapt to breed in *Anopheles* breeding sites (Trpis *et.al.*, 1981; Paploski *et.al.*, 2016). Therefore, this research will be able to enlighten all aspects of mosquito control efforts, not just those targeting *Aedes* mosquitos. The primary goal was to gather social, environmental, epidemiological, entomological, and organizational information that could help the government create more effective interventions. The study utilized the PRECEDE portion of the PRECEDE-PROCEED planning model to inform the design. We also employed Community Based Participatory Research methods to ensure the project meets the needs of the community thoroughly and had components that can lead to sustainability in the implementation of programs directed at reducing the mosquito population in Belize.

2. Methods

2.1 Theoretical Framework

2.1.1 CBPR as a strategy for community engagement

Community Based Participatory Research or "CBPR" is an established research and intervention strategy that has been shown to have success in developing culturally appropriate interventions and providing the context for those interventions to continue over time (Espino *et al.*, 2012; Israel *et al.*, 2010; Sommerfeld and Kroeger, 2015). The importance of CBPR is that it goes beyond just working with a community in a researcher-participant relationship. Instead, the CBPR approach treats the community as partners in the research, where they define and identify the problem, are trained as researchers, and they share equal responsibility and control over the implementation and findings (Hacker, 2013). One of the most famous CBPR approaches is that of Paul Farmer's organization, "Partners in Health." Partners in Health began as a CBPR project to combat tuberculosis in Haiti and is now a network of research and intervention projects in ten countries around the world (Partners in Health, 2016).

Major strengths to this approach include increased capacity, bridging communities to the academic and international world, increased community efficacy in relation to problem solving, and increased likelihood of sustainability and change (Hacker, 2013). These methods have also been employed in many parts of the world to bring about behavioral change and reduce disease incidence (Espino *et al.*, 2012; Sommerfeld and Kroeger, 2015). Mosquito control can increase greatly, by instigating this team and community centered approach and relying on the strengths of CBPR to decrease health disparities related to vector-borne diseases. It may even replace or supplement the need for insecticides and genetically modified vector control.

2.1.2 PRECEDE-PROCEED model for program planning

The PRECEDE-PROCEED planning model is an eight-phase process that investigators use as a template, for health and community assessment, intervention planning, implementation, and evaluation (McKenzie et al., 2017). The model works backwards by identifying the outcomes of a health problem, then identifying what causes the outcomes, starting from the community perception of their health issues (social assessment), designing and implementing well-informed programs or interventions to target these causes, and finally develop the interventions with sound evaluation (McKenzie et al., 2017). The PRECEDE portion contains the first four phases. Each phase is an assessment that collects information on the community in relation to a health issue. The PROCEED portion of the model is the last four phases and covers program implementation and evaluation. Due to the time constraints and limited resources, this study was only able to complete the PRECEDE portion of the model. Our research team and community stakeholders plan to conduct the PROCEED phase sometime in the future.

Phase one is a social assessment which seeks to identify the priorities and needs of the target population or community. Within the study, these needs and priorities are analyzed based on their relation to mosquitos and mosquito borne diseases. The model emphasizes that the target population should be directly involved in the assessment and should identify their own needs and issues (Section 2. PRECEDE/PROCEED, 2016). This was addressed by using CBPR to research community perceptions, inform community involvement, design stakeholder consultations, and design the questionnaire.

Phase two focuses on epidemiological factors and environmental factors related to the health problem identified in phase one. This particular study gathered multiple secondary data resources including, epidemiological and entomological data to fulfill this assessment. Analysis of this phase involved ranking and identifying important factors, found from the data, on their level of importance for targeting in a future intervention.

Phase three is a behavioral assessment that looks at behaviors in three categories; predisposing, enabling, and reinforcing. In other words, identifying baseline knowledge and perceptions, barriers or facilitators of health and resource access, and feedbacks to continue or discontinue behaviors (McKenzie *et al*., 2017). This assessment informed the design and analysis of the questionnaire for the given study.

Finally phase four is an administrative and policy assessment, and intervention alignment. The assessment is used to identify the different policies established by the Ministry of Health (MOH) for mosquito vector control at community, local and central levels, as well as the policy effectiveness and gaps. Also, phase four focuses on how invested the stakeholders are in a potential program. Using the assessment findings of the previous four phases, this intervention alignment phase helps to tailor scientifically sound interventions to achieve expected results. This study implemented this assessment by using stakeholder consultations, a technique found in CBPR research, as well as observations recorded while working and shadowing stakeholders. This is because the model emphasizes that the most valuable data for informing a successful program will be gathered if the community and stakeholders are involved in the planning, identification, and ownership of results (McKenzie *et al.,* 2017).

2.2 Study Design

The study utilized a mixed methods approach to develop a needs assessment based on the PRECEDE-PROCEED model. The following is a list of the methods that were used.

1. A six domain, open-ended questionnaire was designed to measure the risk factors, perceived and actual needs, practices, behaviors and possible improvements that could be made within the community about mosquito eradication and spread of disease. The questionnaire combined the four phases of the PRECEDE model in order to simplify measurement and decrease the time needed to complete the assessments.
2. GPS location methods were used to assist analysis of environmental factors that may impact the community and vector control.
3. Observational data was collected in order to analyze the polices and organizations that contribute to vector control efforts.
4. Secondary epidemiological and entomological data was obtained from the Ministry of Health and the Western Regional Vector Control Unit.

5. Stakeholder consultations were scheduled and held, in CBPR fashion, in order to ensure the community was involved in most parts of the research design and implementation.

The study also went through three Institutional Review Board (IRB) approvals. The first approval was granted from Duke Kunshan University, the second from the National Institute of Social and Cultural Research in Belize, and the third was from the Belizean Ministry of Health ethics review board. To comply with the IRBs, the research team provided informed consents in English and Spanish, were trained to answer any questions, and provided adequate contact information to participants for future follow-up if need be.

2.2.1 Goal

Assess the perceptions, knowledge, environmental risks, epidemiological risks, behaviors, and gaps in policies that are associated with mosquito control in the Belmopan, Belize community

2.2.2 Objectives

- Assess social, epidemiological, behavior, environmental, and health policy and administrative factors that are associated with mosquito control in the Belmopan community in Belize.
- Use the findings from the scientifically based assessment as evidence for decision making.

- Identify the significant predisposing, reinforcing, and enabling behaviors that contribute to mosquito control and disease prevention.
- Assess the most vulnerable geographic and social areas for mosquito population increase and possible disease outbreak.
- Capacity strengthening at community level to conduct research based community program planning for long lasting solutions.
- Identify community specific needs and perceptions in regards to mosquito control and their related diseases in order to inform the stakeholders of future program focus.
- prioritize the most important preventive measures for future outbreaks in the community.

2.2.3 Research Question

This research answers the question, “Does a community-based approach to program and policy implementation result in improved community involvement and better health planning to eradicate vector-borne diseases in Belize?”

2.3 Study setting

The chosen location is the city of Belmopan, the capital of Belize. The project took place within the city limits since the *Aedes* mosquitos greatly affects urban areas (Morrison *et al.*, 2008). This is a small city with a population of 20,000 people with mixed ethnic backgrounds such as Mayan, Mennonite, Mestizo, Creole, Indians, and other Central American ethnicities. The population is greatly dispersed throughout the city, and many live on the outskirts of the city limits. The city has an area of 32.78 km^2.

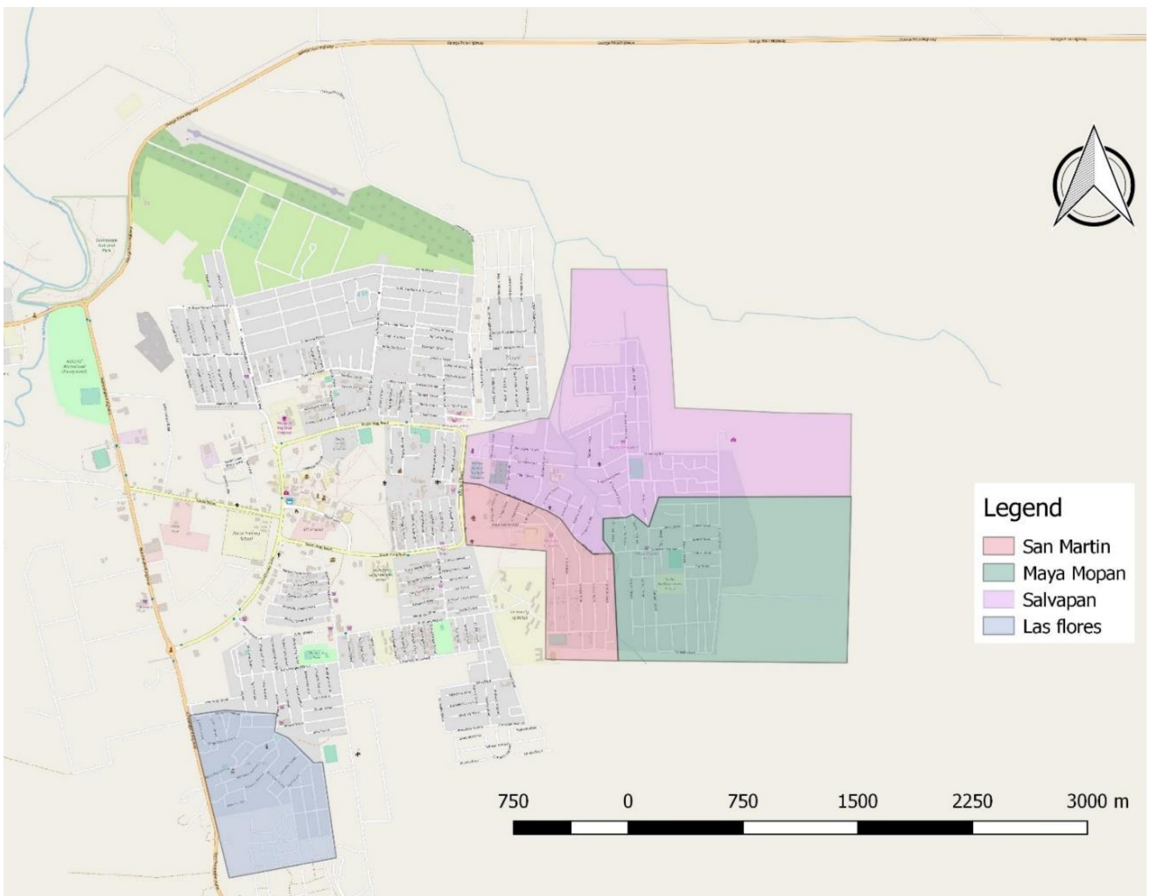


Figure 1: Communities of Belmopan, Belize, 2017

Particular focus was given to the communities of San Martin, Salvapan, Maya Mopan, and Las Flores (Figure 1). These communities were once refugee settlements and had local leaders, therefore they became classified as independent villages. Once the Belmopan city council was established, they were integrated as part of the main city and the local leaderships dissolved. Now they are part of the Belmopan city limits, but have stablished individual community identities with unique attributes and peoples. These communities were identified by stakeholders to be the problem areas for vector control.

2.4 Procedures

2.4.1 Stakeholder Consultation

To fulfill the requirement of the CBPR model, three stakeholder consultations were organized with the relevant stakeholder groups. Upon arrival to Belize, in late April 2017, introductory meetings were organized with the Ministry of Health to begin setting up working relationships and introducing the project. It took approximately a month to meet and organize five organizations and nine representatives. Organizations that were committed to the consultation were; the Ministry of Health, Western Regional Vector Control Unit, the University of Belize (UB), the National Institute of Social and Cultural Research, and the Belmopan City Council.

The first stakeholder consultation was scheduled for early June before data collection could commence. The Primary Investigator and I, along with the research team, introduced the project, presented on the results of the pre-test for the questionnaire, and gathered stakeholder inputs on the design and format of the questionnaire. The research team was also recording notes and observational data to be analyzed in order to understand how stakeholders interacted, and how their goals were aligned. This meeting was not visually or voice recorded for ethical reasons.

The second stakeholder consultation occurred after data collection was completed. This meeting informed the stakeholders about the success and failures of data collection, preliminary findings of the questionnaire, and the future goals for analysis. The third and final stakeholder meeting were also discussed.

The final stakeholder meeting will take place in January 2018. This meeting will inform the stakeholders as well as more community members of the research outcomes and analysis. Recommendations for future programs and reevaluation of polices will be presented. The goal of this meeting will be to demonstrate the importance of community efforts to help continue to effectively control mosquitos within the area and perhaps begin assisting in the planning of a complete program.

2.4.2 Questionnaire Design

The questionnaire was predesigned, before entering the field in April 2017, as a mix of open-and-closed ended questions. This initial survey was used to assist in training of the research assistants' and was consistently revised through research assistant and local input to improve the validity of the information gathered.

The questionnaire was then pre-tested to ensure that it was relevant to the targeted population. The Sondeo method was employed in this study in order to gather a rapid assessment of whether questions and problems discussed in the questionnaire were relevant to the population (Galindo and Israel, 2008). The method was first created by the

Guatemalan Institute of Agricultural Science and Technology and is a recognized participatory method (Hildebrand, 1981). It was established to fill the need for a multidisciplinary approach that was quick, efficient, cheap, and able to be carried out in areas that are not defined by strict boundaries (Hildebrand, 1981). The Sondeo method is normally unstructured with a few identified conversation topics that result in a conversational interview (Galindo and Israel, 2008). Interviews are conducted with two or more interviewers and sometimes results in a small group or focus group discussion. Interviewers are encouraged not to take too many notes during the interviews but develop a summary after each interview is completed. Reporting of the results is done in a systematic way by coding and grouping relevant information. Final results are agreed upon by the whole team before official reporting occurs (Galindo and Israel, 2008).

The Sondeo method was modified to fit the needs of the pre-test. The method was employed both as an assessment and a training instrument. Five general questions covering perceptions of mosquitos, the diseases they carry, and practices to prevent mosquitos were asked of participants. Research assistants went in teams of two and eventually split up to cover more ground individually. The purpose was for them to become comfortable asking questions and become familiar with being rejected by potential participants. Pre-test interviews were conducted house to house in neighborhoods within Belmopan that were part of the immediate target population for the main questionnaire. Data was also collected at the local market days to target a wider audience and give the research assistants a different environment in order to hone their interview skills. The research assistants accumulated their reports and data was coded or entered into an easily viewable graph. They then presented their findings at the stakeholder meeting and the results were used to further narrow the questionnaire to fit the target population.

The final questionnaire covered six domains: mosquito knowledge and perceptions, disease knowledge and perceptions, practices to prevent mosquitos from biting and breeding, observations, government practices and perceptions, and demographics. All questions were designed to be open-ended with few close-ended questions in order to make the survey more conversational and hopefully gather more information from participants. Also, it was found during the pre-test and stakeholder consultation that Belizeans are more responsive to conversational surveys. Questions were also designed to be read by the research assistant to the participant. Research assistants were then given word banks of possible answers that were informed by the pre-test and stakeholder consultation, as well as blank spaces to write additional notes and observations for each question. The assistants were able to give the questionnaires in Spanish, English, Maya Mopan, and K'iche' Maya. After each questionnaire was completed, the research assistants would review and write any additional information or observations they were unable to gather while speaking with the participant. They would then record a GPS coordinate for the household surveyed. Summaries of each questionnaire were written up by the assistants at the end of each collection day.

2.4.3 Training

The research team consisted of four students, hired from the University of Belize. One of the students was using the experience to fulfill an internship requirement for a class. Therefore, some of the research requirements for him were stricter than for the other three. This also fit well with the CBPR model as it strengthened the capacity of the local students to conduct and become interested in further research endeavors.

Training occurred for five days. The interviewers were informed of the overall project and theories behind the design. Mainly they were thoroughly versed in ethics of research and given scenarios to act out and analyze to ensure the concepts were understood. The final steps of training were to go over the questionnaire, role play possible scenarios for interviewing, and then conduct the pre-test. During the pre-test, the members were assessed for their language usage and understanding, as well as how they interacted with participants.

Training was an ongoing process after data collection started. The assistants were accompanied every day for the first two weeks to ensure data quality and consistency. They were given individual and group notes after each survey and work day. Eventually they were only assessed periodically to ensure data quality was being upheld.

Figure 2: Training and assessment held at the University of Belize

2.4.4 Sampling

The target population was Belmopan residents in the communities of San Martin, Salvapan, Maya Mopan, and Las Flores. The units of analysis were households because the study focuses on group and community behaviors, not just those of the individuals. As the communities are socially established and not officially politically recognized, it proved difficult to determine community boundaries. Locals and stakeholders informed the team that streets named after saints were located in San Martin, streets named after countries were in Salvapan, streets in Mayan were in Maya Mopan, and streets in Spanish were in Las Flores.

The team conducted convenience sampling of households while proportionally sampling the communities based on household data received by the Western Regional

Vector Control Unit. This is not a statistically representative sample due to the lack of randomization; however, it is still thought to be representative of the population due to the coverage of the communities. The research team went house to house asking to interview permanent household residents over the age of 18 who were willing to be surveyed. The chosen resident was to be a representative of the entire household and their daily practices. If they did not feel they could speak for the whole, another member would be asked to assist or complete the survey. If a household was unable to complete the survey, the team would attempt to return; however, if the survey stayed incomplete it was not used for analysis.

2.4.5 Observations and Secondary Data Collection

Observations were conducted throughout the study on stakeholders, their internal and external organizational interactions, reactions and perceptions of issues related to the topic, and their current actions being taken to target vector control. These observations were carried out during interviews, data analysis, and shadowing opportunities. Usually the Co-investigator was the primary observer, but, occasionally the entire research team was present. When the entire research team was present, each assistant would take separate notes that would later be combined by the Co-investigator for coding and analysis. Discussions to debrief on the situation and observations would also be conducted shortly after the shadowing or meeting. At times, the research team also acted as a stakeholder of the community because they were able to provide feedback from the viewpoint of students attending the University of Belize, which was within the targeted population area.

Secondary data was provided by the Ministry of Health and Western Regional Vector Control Unit. The epidemiological data, provided by the MOH, contained information on dengue from 2013 to 2016, zika in 2016, and chikungunya from 2014 to 2015. Two separate data sets were provided. The first was cleaned and organized by looking through the Belize Health Information System (BHIS) to determine if the cases were within the targeted communities. Inconsistencies began to arise, and another data set was requested. The second data set was unable to be cleaned due to lack of time in the field. However, it was compared to the first data set as much as possible and any cases that were missing from the second data set were added from the first.

The Western Regional Vector Control Unit provided the entomological data. The data includes Breteau, household, and container indices, for the targeted communities. This data set ranges from 2013 to 2016 however not every year contains data on the communities and data from 2015 was lost or missing. These inconsistencies can be explained by the lack of funding or lack of need for vector control within the communities for the given year.

2.4.6 Data Analysis

The questionnaires were analyzed using STATA 15 and NVIVO 11. Questions that were quantifiable were entered into a data set and analyzed using Chi-squared tests, a Shapiro-Wilk's test, and logistic regressions. In order to meet the parameters of the logistic regression tests, some variables had to be combined to ensure that there were enough respondents in each category. A Fisher's exact test was used to determine if there was any relation between variables, if the number of cases was insufficient for a given variable.

Other questions were coded and themed in NVIVO 11 to determine commonality among respondents. Binomial generalized additive models were used to investigate the relationship between variables and geography. This was done using the *brms* package in the statistical programming language R (Bürkner, 2017). Other maps were created in QGIS. Epidemiological and entomological data was also analyzed using STATA 15 and QGIS.

3. Results

3.1 Primary Data Collection

3.1.1 Household Demographics

Distribution of households surveyed is shown in Figure 3. Each map point represents a GPS coordinate identifying a household that was surveyed within the outlined community boundaries. Four households were omitted from this map and further spatial analysis because the coordinates were not collected. The average accuracy of the coordinates was 20.89 meters.

We attempted to proportionally sample each village. Basing estimations of the total number of households per community on data provided by the Western Regional Vector Control Unit, we calculated that approximately 8-10% of the total households within each community were surveyed successfully. There were 236 households surveyed with a total of 40 surveyed in San Martin, 74 in Salvapan, 65 in Maya Mopan, 49 in Las Flores, and 8 in Belmopan. The eight households in Belmopan were omitted due to not being within the target communities leaving 228 households for analysis.

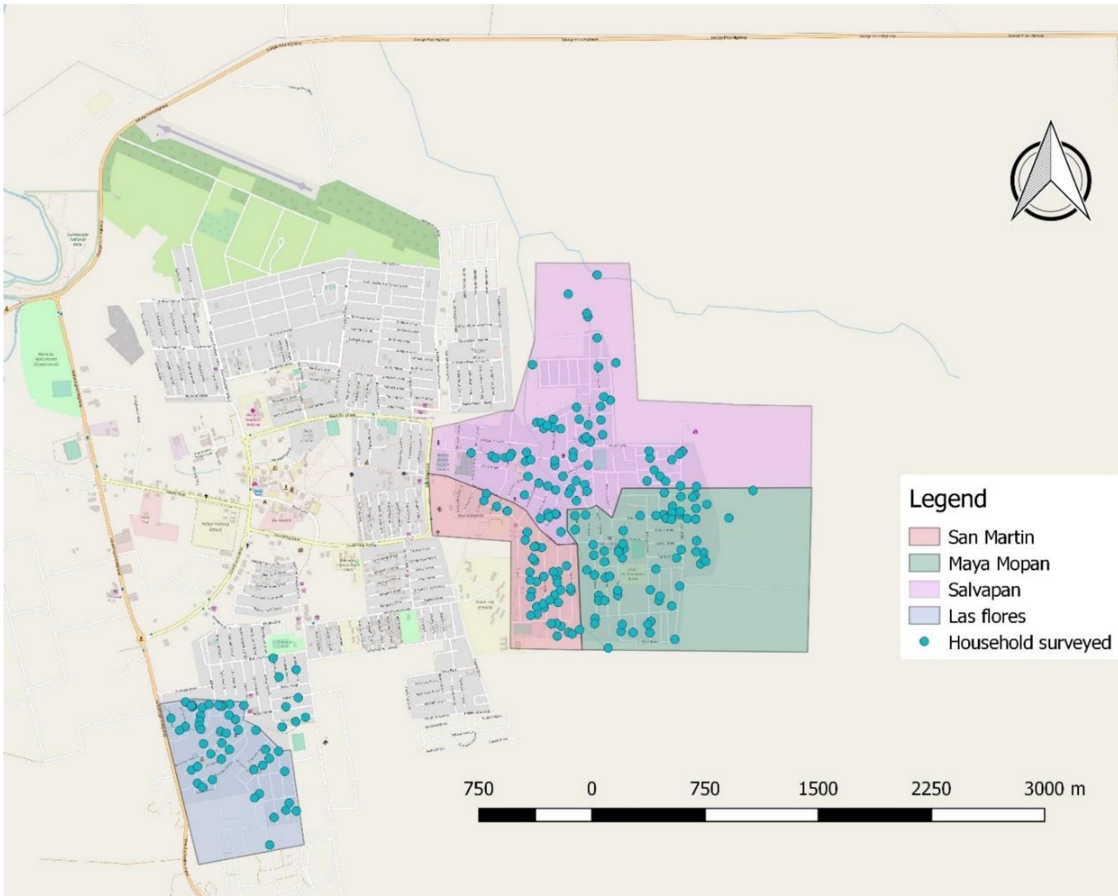


Figure 3: Communities of Belmopan, Belize and marked coordinates of studied households

Household sociodemographic characteristics are presented in Tables 1 and 2 and Figure 4. Of the households surveyed, 32.46% were located in Salvapan, 40.77% had a monthly income of less than 1000 BZE, 45.81% were Mestizo, and 46.70% said Spanish was the main language of the house. The average household size was 5, with 55.95% of households having about four to six people living in each home. The eldest person living in each house was an average age of 46.63 years old, with 51.39% of households having the eldest individual between the ages of 30 and 50. Heads of households made up 40.53%

of individual respondents; however, the majority were either the spouse or child of the head of household, making up 51.55% of respondents.

Table 2 is divided into the characteristics of the respondent and the characteristics of the head of the household. Respondents were asked to give their own characteristics and, then as acting representative of the entire household, to provide as much information on the head of the household that they knew. If the respondent was the head of the household, then they were included in both categories of the table. Respondents may have refused to answer or could not recall characteristics; therefore, the sums of N are not complete. The majority of respondents had a primary or secondary education, whereas almost 50% of the heads of households had only a primary education. Of the respondents, 46.90% said they did not hold a formal job but stayed in the home and held domestic responsibilities. Another 10.18% were in business or sales. This can be attributed to the fact that during the hours in which surveying took place, many times the only people in the household to respond would be those who worked from home. Occupation of the heads of households varied more so than respondents. Most worked from home, in a technical field, or in a security related job.

Table 1: Sociodemographic characteristics of studied households, Belmopan, Belize, 2017

Variable (N=228)	Number	Percent
Location		
San Martin	40	17.54
Salvapan	74	32.46
Maya Mopan	65	28.51
Las Flores	49	21.49
People per household		
1-3	45	19.82
4-6	127	55.95
7-9	37	16.30
10-12	11	4.85
13-15	5	2.20
16-18	2	.88
Eldest person in the household		
19-29	21	9.72
30-39	62	28.70
40-49	49	22.69
50-59	38	17.59
60-69	32	14.81
70-79	10	4.63
80-89	4	1.85
Respondents relation to the head of the household		
Head	92	40.53
Spouse	67	29.52
Child	50	22.03
Grandchild	4	1.76
Parent	3	1.32
Sibling	4	1.76
Distant relation/Not related	7	3.08
Monthly income (BZE) of household		
0-999	53	40.77
1000-1999	56	43.08
2000-2999	11	8.46
3000-3999	6	4.62
4000-4999	4	3.08
Ethnicity of household		
Mestizo	104	45.81
Hispanic	49	21.59
Maya (undefined)	10	4.41
Mopan Maya	27	11.89
K’ekchi’ Maya	25	11.01

Creole	7	3.08
Garifuna	1	.44
Belizean American	1	.44
Indian	2	.88
German	1	.44
Languages spoken in the household		
Spanish	106	46.70
Mopan Mayan	12	5.29
K'ekchi' Mayan	9	3.96
Creole	18	7.93
English	14	6.17
A non-English language and English/creole	58	25.55
Multiple non-English languages and English/Creole	7	3.08
Multiple non-English languages	3	1.32

Table 2: Education and occupation of study respondents and heads of the household, Belmopan, Belize, 2017

Variable (N=226)	Respondent		Head	
	Number	Percent	Number	Percent
Education				
None	28	12.44	33	16.26
Primary	97	43.11	100	49.26
Secondary	73	32.44	49	24.14
Higher	27	12.00	21	10.34
Occupation				
Domestic	106	46.90	40	17.70
Student	17	7.52	0	0
Business, sales, vendor	23	10.28	30	13.27
Carpenter, construction, mason	10	4.42	40	17.70
Electrician, mechanic, technician	5	2.21	13	5.75
Security, police	6	2.65	25	11.06
Government, teacher	5	2.21	6	2.65
Janitor, cleaner	12	5.31	8	3.54
Restaurant, cook staff	7	3.10	7	3.10
Caretaker, babysitter	4	1.77	1	.44
Tour guide, resort staff	2	.88	1	.44
Farmer	4	1.77	14	6.19
Driver	5	2.21	19	8.41
Various, misc.	11	4.87	15	6.64
Unemployed/retired	9	3.98	7	3.10

Sum of N for some variables may not equal total N due to missing responses

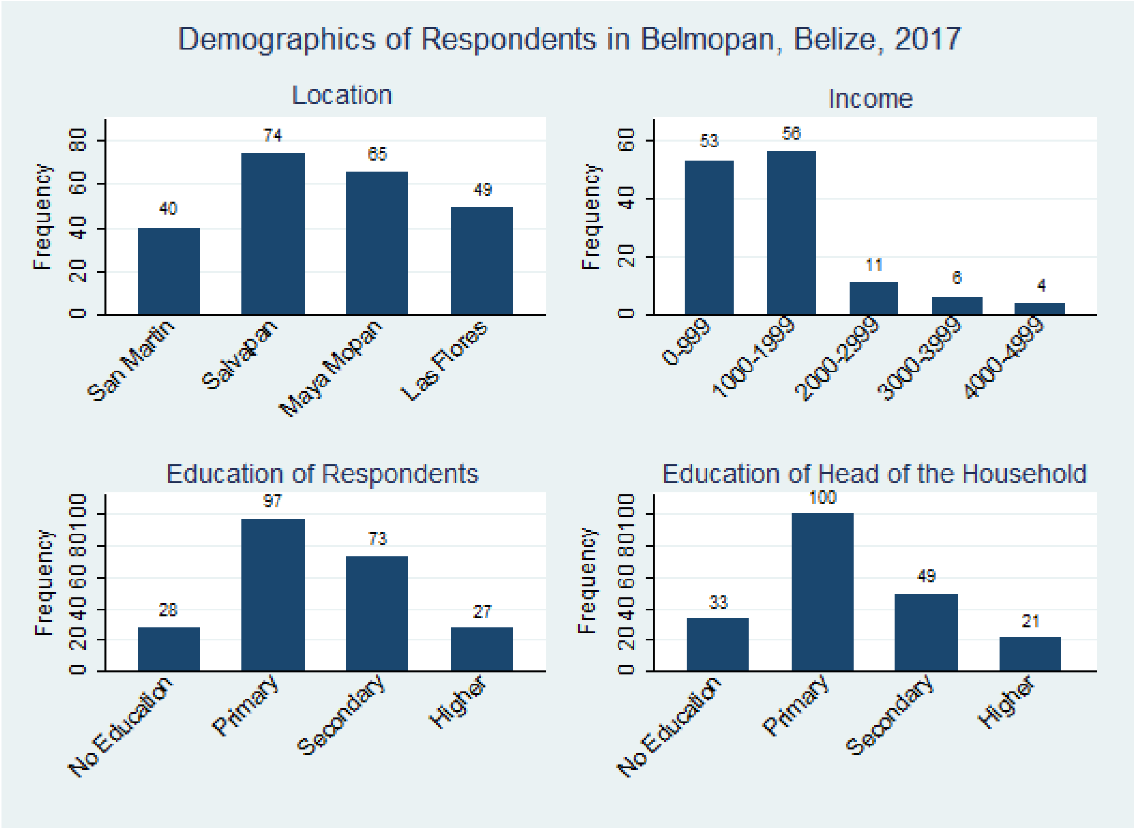


Figure 4: Selected demographic characteristics of respondents in Belmopan, Belize, 2017

3.1.2 Knowledge and Perceptions

Tables 3 and 4 summarize the sources of information that respondents reported where they have gained knowledge about mosquitos and the diseases they carry (Figures 5 and 6). Some national TV and Radio broadcasts are supported by the MOH; however, other sources may be international news broadcasts, cable TV programs, and general reports made by Radio broadcasters. MOH specific sources were in the form of posters, handouts, and health inspectors who would visit households. Hospital sources not only included information from doctors but also any health education posters that were exhibited in the halls.

For sources of information on mosquitos, 41.23% of respondents reported the MOH as their primary source. Radio sources (37.28%) and Hospital sources (35.09%) were also highly reported. It is concerning that only 0.44% receive information from the City Council. The few number without access indicates that mosquito education is reaching the majority of the population, however if the goal is to provide information to 100% of the population then there is still room for improvement.

Table 3: Sources of information on mosquitos

Source (N=228)	Yes	No
	Number (%)	Number (%)
TV	69 (30.26)	159 (69.74)
Ministry of Health	94 (41.23)	134 (58.77)
Hospital	80 (35.09)	148 (64.91)
City Council	1 (.44)	227 (99.56)
Radio	85 (37.28)	143 (62.72)
Child's School	17 (7.46)	211 (92.54)
Respondent's School	60 (26.32)	168 (73.68)
Neighbors and Friends	11 (4.82)	217 (95.18)
Online	37 (16.23)	191 (83.77)
Family	7 (3.07)	221 (96.93)
No Access	3 (1.32)	225 (98.68)

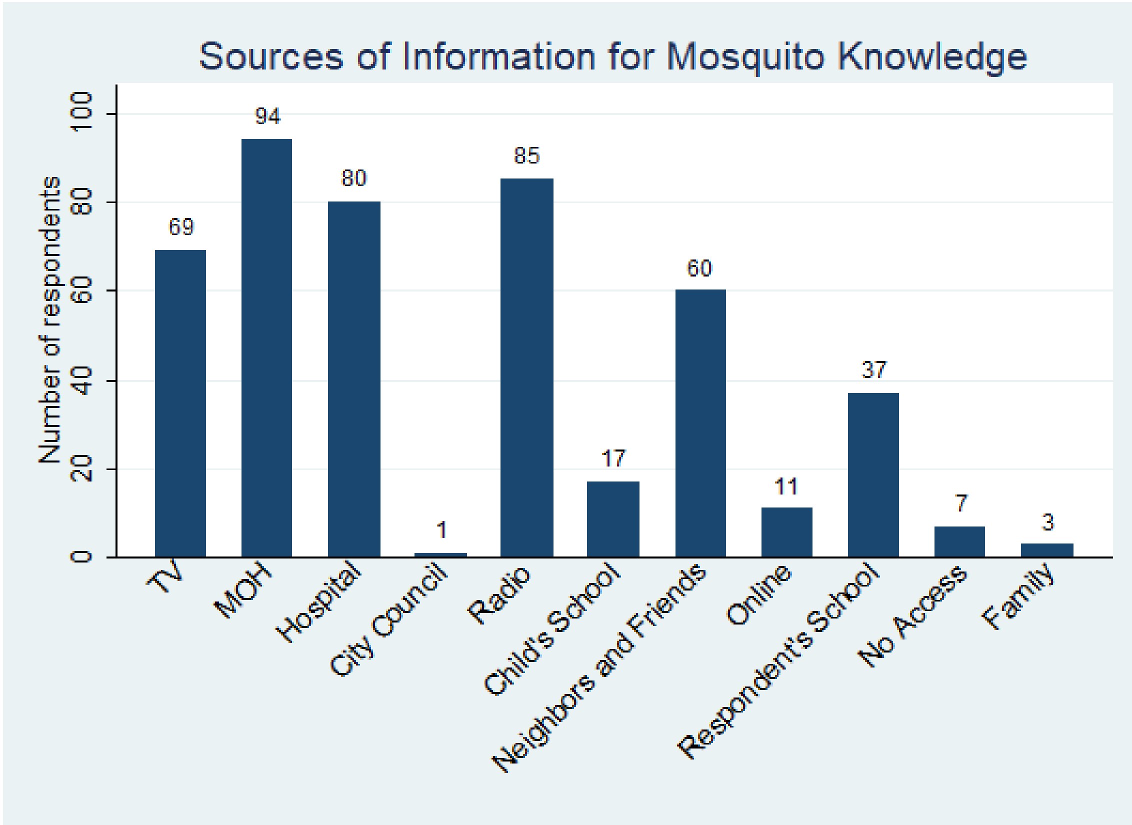


Figure 5: Reported sources of information used to gain knowledge about mosquitos in Belmopan, Belize, 2017

Dengue information sources were more distributed, with the majority of respondents (31.14%) gaining access to information from the Hospital. MOH, TV, and personal experiences were the next most reported sources of information. Both MOH sources (25.44%) and personal experiences (21.05%) were reported more for dengue-related information than the other three diseases.

Zika-related information was reported being found mostly from TV (35.09%) and Radio sources (29.39%). In fact, zika had the highest reporting for TV-related sources across the disease categories. Knowledge gained from personal experience (1.32%) was much lower for zika than the other diseases; however, online/book research (5.7%) was reported more than any of the other disease categories. These patterns can be attributed to the fact that zika was greatly publicized by national and international news broadcasts. Personal experiences were lower simply because the zika outbreak had only just occurred in 2016 and fewer people have been affected.

Chikungunya information sources followed a similar pattern as those reported for zika. Radio (30.70%) and TV (25.44%) had the highest reporting and Radio was reported more for chikungunya than for the other diseases. Malaria information sources had the most evenly distributed reporting with Radio (28.07%), Hospital (25.88%), TV (25%), and MOH (20.61%) related sources having similar percentages. Overall, the lowest reported sources were from City Council and a Child's School.

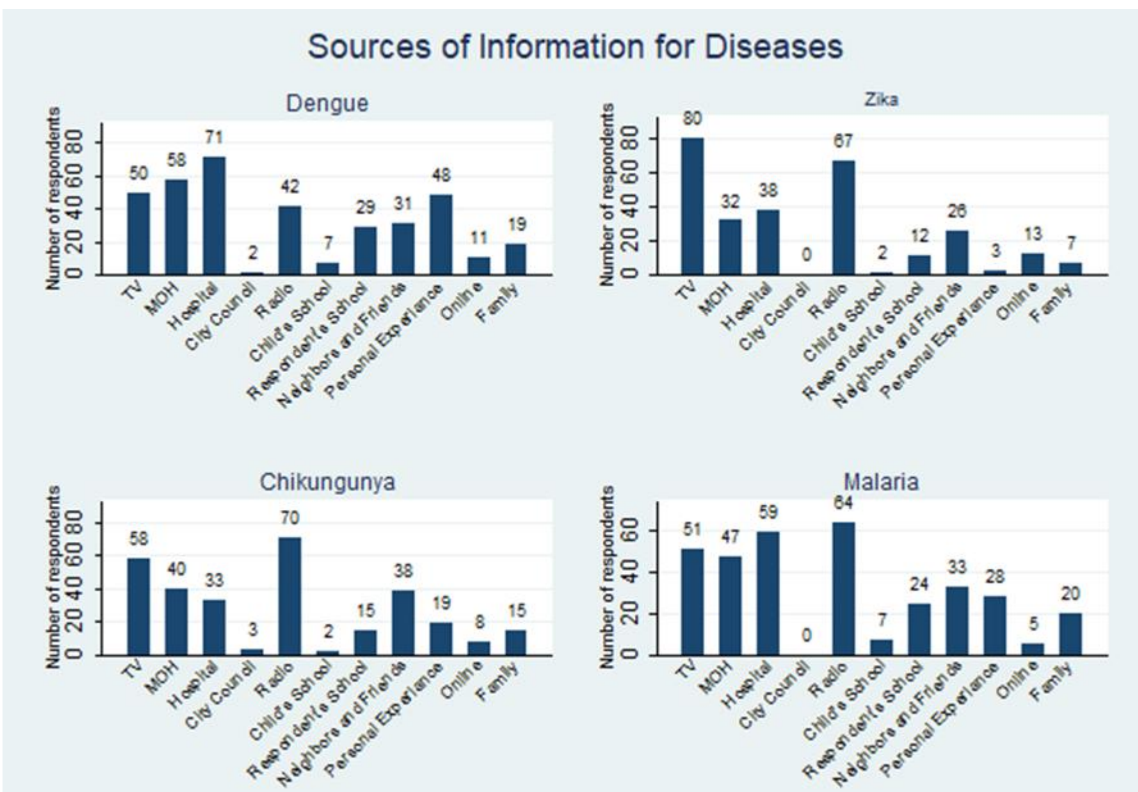


Figure 6: Sources for disease related information in Belmopan, Belize, 2017

Table 4: Sources of information on dengue, zika, chikungunya, and malaria

Source (N=228)	Dengue		Zika		Chikungunya		Malaria	
	Yes	No	Yes	No	Yes	No	Yes	No
	Number (%)	Number (%)	Number (%)	Number (%)	Number (%)	Number (%)	Number (%)	Number (%)
TV	50 (21.93)	178 (78.07)	80 (35.09)	148 (64.91)	58 (25.44)	170 (74.56)	51 (25.00)	171 (75.00)
Ministry of Health	58 (25.44)	170 (74.56)	32 (14.04)	196 (85.96)	40 (17.54)	188 (82.46)	47 (20.61)	181 (79.39)
Hospital	71 (31.14)	157 (68.86)	38 (16.67)	190 (83.33)	33 (14.47)	195 (85.53)	59 (25.88)	169 (74.12)
City Council	2 (.88)	226 (99.12)	0 (0)	228 (100)	3 (1.32)	225 (98.68)	0 (0)	228 (100)
Radio	42 (18.42)	186 (81.58)	67 (29.39)	161 (70.61)	70 (30.70)	158 (69.30)	64 (28.07)	164 (71.93)
Child's School	7 (3.07)	221 (96.93)	2 (.88)	226 (99.12)	2 (.88)	226 (99.12)	7 (3.07)	221 (96.93)
Respondent's School	29 (12.72)	199 (87.28)	12 (5.26)	216 (94.74)	15 (6.58)	213 (93.42)	24 (10.53)	204 (89.47)
Neighbors and Friends	31 (13.60)	197 (86.40)	26 (11.40)	202 (88.60)	38 (16.67)	190 (83.33)	33 (14.47)	295 (85.53)
Personal Experience	48 (21.05)	180 (78.95)	3 (1.32)	225 (98.68)	19 (8.33)	209 (91.67)	28 (12.28)	200 (87.72)
Online/Books	11 (4.82)	217 (95.18)	13 (5.70)	215 (94.30)	8 (3.51)	220 (96.49)	5 (2.19)	223 (97.81)
Family	19 (8.33)	209 (91.67)	7 (3.07)	221 (96.93)	15 (6.58)	213 (93.42)	20 (8.77)	208 (91.23)

Table 5: Knowledge scores about diseases and mosquitos among respondents of Belmopan, Belize, 2017

Variable (N=228)	Number	Percent
Dengue Knowledge		
0	2	.88
1	64	28.32
2	42	18.58
3	118	52.21
Zika Knowledge		
0	22	9.69
1	153	67.40
2	29	12.78
3	23	10.13
Chikungunya Knowledge		
0	13	5.70
1	151	66.23
2	24	10.53
3	40	17.54
Malaria Knowledge		
0	5	2.21
1	88	38.94
2	42	18.58
3	91	40.27
Mosquito Knowledge		
1 or less	13	5.70
2	32	14.04
3	74	32.46
4	66	28.95
5	33	14.47
6	8	3.51
7	2	.88
Combined Score		
20-29%	5	2.20
30-39%	27	11.84
40-49%	55	24.13
50-59%	65	28.51
60-69%	56	24.57
70-79%	11	4.83
80-89%	8	3.51
90-100%	1	.44

Sum of N for some variables may not equal total N due to missing responses

Table 5 reports the knowledge score of individual respondents. In order to score disease knowledge, participants were asked what they knew about each of the diseases. Responses were recorded and then scored based upon what was reported. The respondent received a score of 0 if they had never heard of the disease before. A score of 1 was assigned if they had heard of it or knew it was carried by mosquitos. A score of 2 was assigned if they could identify one symptom correctly or a special characteristic of the disease like transmission, and a score of 3 if they could identify more than one symptom accurately and a special characteristic of the disease. Mosquito knowledge was scored differently. Participants were asked what they knew about mosquitos, if they could identify or describe a particular kind of mosquito, and if they were able to identify the correct mosquito type from the picture shown. A total of seven topics were identified; whether a mosquito breeds in water, type of water they breed in, which mosquito bites, do mosquitos breed in man-made containers, can name or describe a specific mosquito type, and can identify the mosquito in the picture given to them. A point was given for each correct answer with a total of 7 points available. Finally, a person's total score was calculated by adding up the scores from each category. Nineteen possible points were available.

Respondents were most knowledgeable about dengue (3=52.21%) and malaria (3=40.27%) and least knowledgeable about zika (1=67.40%) and chikungunya (1=66.23%). Also, zika had the highest percentage of people (9.69%) who had never heard of the disease before. Zika and chikungunya have only recently been introduced into the population; therefore, it is understandable that fewer would know about these diseases. Participants were mostly awarded 3 (32.46%) or 4 (28.95%) points for mosquito knowledge. It is important to note that only 11% of respondents were able identify a rash, a very notable identifier of dengue, zika, and chikungunya, as a specific symptom. A few respondents did not believe the information they had received about the diseases. For example, one respondent did not believe that mosquitos carried diseases despite what others had told her. Another believed "*that all the diseases were the same disease, only renamed* *so doctors could make more money*" (Field notes, June 2017). This respondent had worked at a community health facility and had a strong knowledge of all the diseases.

It is interesting to note that when asking about mosquitos some respondents had mixed reactions to the questions. Some recognized their lack of knowledge and mentioned later that future information should focus on mosquitos not just the diseases they carry. However, some had an apathetic response. These respondents mentioned that mosquitos were beyond their control and did not understand why the average individual should care about specific characteristics of mosquitos. These more apathetic individuals normally saw mosquitos as an occasional nuisance but not a major concern.

A Shapiro-Wilk test was conducted to determine if total combined scores were normally distributed (Figure 7). The P-value (.42028) was not significant at a 95% confidence interval. This means that the null hypothesis cannot be rejected and that the scores are normally distributed. If the sample collected was representative of the population, despite not being a random sample, then it can be concluded that approximately 68% of the population will have a knowledge score of 7.68 (40.4%) to 12.81 (67.4%) out of 19 (100%) possible points.

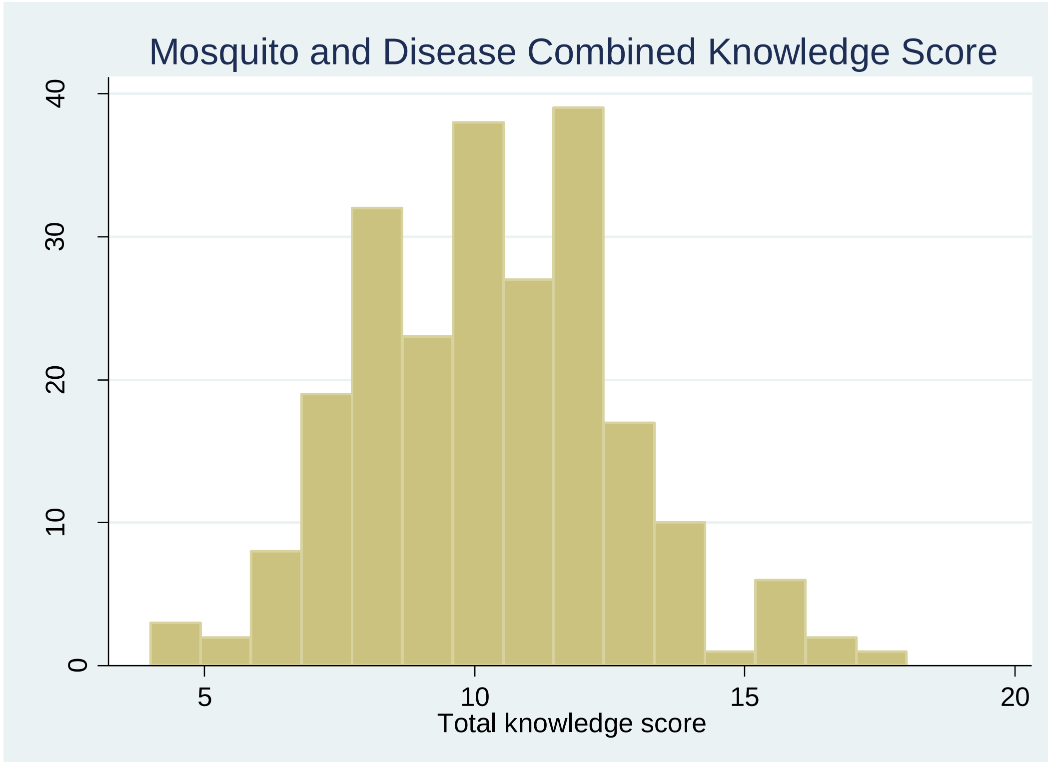


Figure 7: Histogram demonstrating normal distribution of knowledge scores for respondent in Belmopan, Belize, 2017

As shown in Table 6, respondents were able to voice their perceptions of mosquitos, diseases, and health promotion programs for the future. The majority of respondents recognized mosquitos (94.64%) to be a problem for the community. This may be over reported as our survey is about mosquitos; therefore, respondents may be biased to answer positively as that is what they perceived we wanted to hear.

Certain themes occurred as to why mosquitos were a problem, such as mosquito bites cause irritation, the mosquitos carry diseases, specific environmental factors increase mosquito populations, and preventative measures are not taken. People found mosquitos to generally be a nuisance and their bites can cause allergic reactions and sleepless nights. Respondents also recognized that mosquitos were able to easily transmit disease and that those most affected were children and babies. Although all seasons were identified as having mosquitos, the rainy season was said to be an exceptionally problematic time for mosquitos because it brought stagnant water that would settle in yards and drains.

Others mentioned that mosquitos are a problem because they or their neighbors do not take preventative measures. We asked further what barriers may prevent a household from protecting themselves from mosquitos. The most common issue was that products were too expensive, and the household may become unable to afford some measures. Some respondents mentioned solutions to this problem such as budgeting or prioritizing buying sprays and coils when they first receive their pay check. Others simply bought in bulk when they could afford it, so the supplies would last longer. Inaccessibility of products was also identified as an issue. This may be because the store was too far, mosquito nets were hard to find and replace, or medicines, larvicides, and insecticides were not given out by the MOH. Finally, health issues and environmental factors may prevent households from taking preventative action. Some respondents were elderly or had someone with respiratory issues living in the household. Others found that during the rainy season they were unable to clean or turn over containers as often.

Those who responded that mosquitos might be or are not a problem (5.35%) mentioned a few reasons why. Most stated that they take preventative measures and do not get bit often. Finally, one respondent said that they are simply a nuisance and that problems like crime should take priority over mosquitos.

A large majority of respondents found the diseases mosquitos carry to be a problem for their community (90.54%). Many respondents found that the diseases were easily transmissible, deadly, and that many people in their own neighborhoods had contracted at least one of the diseases. One respondent specifically mentioned how a neighbor had contracted dengue and within the next few weeks the entire neighborhood was sick. Some mentioned that the diseases caused great financial burden and a burden on health and productivity. It was recognized that adults who become sick would not be able to work, or take care of the children, and that children who became sick could not attend school and were at higher risk of death.

Those who responded that the diseases might be or were not a problem (9.46%) commonly said that they had never heard of anyone having the diseases or believed the diseases to be a problem of the past. Rarely respondents took an apathetic approach and mentioned that the diseases and mosquitos were beyond human control so why should they care.

Also, some of the respondents were receptive to participating in future health promotion programs that would target these issues (67.71%). One respondent advised that programs should be about bringing citizens together and cleaning up the community. This would be a faster and cheaper solution than paying City Council employees. The 19.73% who responded maybe or unsure were concerned that they may not have enough time, or it wouldn't be provided in a language they could understand. These respondents were usually still supportive of a future program as they recognized a need for a more informed community.

To increase attendance of future health programs, they need to be provided in multiple languages and accommodate the times that community members are most available. It may be important as well to provide services for children so that parents can attend and not worry about the welfare of their children. Future health programs should also encourage attendees to spread what they learn through their social networks so that the information can spread to those unable to attend. It should also focus on community participation and encourage ownership among the members of the community because vectors do not know boundaries between one person's property and another's.

Table 6: Perceptions on mosquitos, diseases, and future health promotion programs in Belmopan, Belize, 2017

Perception (N=228)	Yes	No	Maybe	Unsure
Are mosquitos a problem for your community?	212 (94.64)	8 (3.57)	2 (0.89)	2 (0.89)
Are dengue, zika, chikungunya, and malaria a problem for your community?	201 (90.54)	17 (7.66)	2 (0.90)	2 (0.90)
Would you be willing to participate in future health programs targeting these issues?	151 (67.71)	28 (12.56)	29 (13.00)	15 (6.73)

Sum of N for some variables may not equal total N due to missing responses

3.1.3 Epidemiology

Table 7 and Figure 8 show respondents' experiences with the diseases of the study. Of the respondents who had contracted a disease, most had contracted malaria (22.81%) or dengue (21.49%). Also, more respondents reported knowing someone who had contracted dengue (15.79%) than any of the other diseases. Of those who contracted the disease, the majority of them sought formal medical treatment and confirmed they had the disease specified. Those who did not seek medical treatment went to a traditional healer or just self-medicated.

Respondents who contracted dengue, chikungunya, and zika were more likely to report having contracted it sometime in the last five years (68.09% and 100%). This corresponds to the recent outbreaks of dengue, chikungunya, and zika that have happened during this time frame. A similar pattern is seen for family members who have contracted these same diseases. Also, some respondents mentioned that they or other family members had contracted the diseases twice, and some were just recently recovering. We cannot make assumptions that all of these cases took place in Belmopan, as we did not collect that information and only some respondents chose to tell us.

Experiences with malaria span over longer time frames as malaria has been endemic within Belize for much longer than any of the other diseases. What is of concern is the high number of individuals within the last five years who have contracted malaria. According to the MOH and Western Regional Vector Control, malaria is no longer a concern for Belmopan. However, 40% of respondents who contracted malaria had gotten it sometime in the last five years where as 65.21% knew a family member who had it in this same time frame. Granted, we were unable to determine if the respondent/family member had contracted malaria in Belmopan specifically; however, some respondents had contracted the disease just the week before being surveyed and had not reported traveling in the recent past. Mosquitos are known to be highly adaptive and can resurface quickly when preventative measures become lax. Perhaps this demonstrates that the Western Regional Vector Control has become more relaxed in their measures against the *Anopheles* mosquitos, and, therefore, we are beginning to see a reemergence of malaria in the community. It is also possible that these cases are what is left of the remaining malaria in the community as it has not been 100% eradicated in Belize; however, it is better to be cautious as mosquitos and their diseases can resurface quickly when they are not made a public health focus.

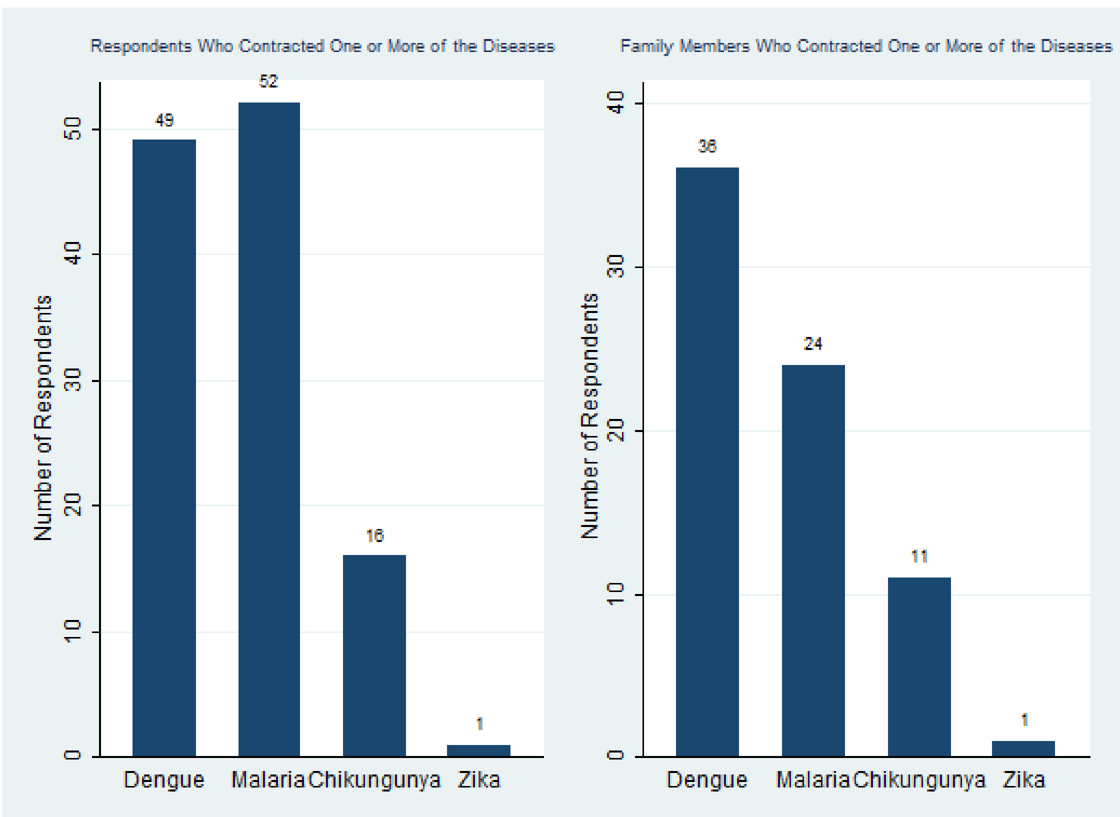


Figure 8: Epidemiology of respondents in Belmopan, Belize, 2017

Table 7: Epidemiology of households in regards to dengue, malaria, chikungunya, and zika in Belmopan, Belize, 2017

Variable (N=228)	Respondent* (n=103)				Family Member† (n=77)			
	Dengue	**Malaria**	**Chikungunya**	**Zika**	**Dengue**	**Malaria**	**Chikungunya**	**Zika**
Contracted Disease								
Yes	49 (21.49)	52 (22.81)	16 (7.02)	1 (.44)	36 (15.79)	24 (10.53)	11 (4.82)	1 (.44)
No	179 (78.51)	176 (77.19)	212 (92.98)	227 (99.56)	192 (84.21)	204 (89.47)	217 (95.18)	227 (99.56)
Years since they contracted the disease‡								
<1	1 (2.13)	3 (6.00)	2 (13.33)	1 (100)	8 (23.53)	3 (13.04)	1 (9.10)	0
1-5	31 (65.96)	17 (34.00)	13 (86.67)	0	23 (67.65)	12 (52.17)	10 (90.90)	1 (100)
6-10	8 (17.02)	8 (16.00)	0	0	1 (2.94)	1 (4.35)	0	0
11-15	4 (8.51)	7 (14.00)	0	0	1 (2.94)	1 (4.35)	0	0
16-20	2 (4.26)	4 (8.00)	0	0	0	2 (8.70)	0	0
21<	1 (2.13)	11 (22.00)	0	0	1 (2.94)	4 (17.39)	0	0
Did they seek medical treatment								
Yes	45 (97.83)	47 (97.92)	11 (78.57)	1 (100)	31 (88.57)	20 (90.90)	8 (72.73)	1 (100)
No	1 (2.17)	0	3 (21.43)	0	1 (2.86)	2 (9.10)	3 (27.27)	0
Don't know	0	1 (2.08)	0	0	3 (8.57)	0	0	0

* Respondents who have contracted at least one disease N=103
† Family Members who have contracted at least one disease N=77
‡ The total of N for each disease category is the total number of individuals who responded yes to having that particular disease.
Sum of N for some variables may not equal total N due to missing responses

3.1.4 Practices and Environmental Observations

Table 8 describes the practices that households use to prevent mosquito bites and mosquito breeding. Fans were reported to be the most used preventative practice in prohibiting mosquito-man contact (84.65%) and used every night. Burning mosquito (Fish) coils (75%), closing doors early (64.91%), use of mosquito nets (51.75%), and bug sprays (46.05%) were also highly reported as preventative measures. Coils, nets, and sprays were used often but some individuals said they may only be used occasionally. This may be due to the uncomfortableness of the product or because they only saw it to be necessary when the mosquitos were particularly bad. Respondents who reported not using Fish coils usually didn't like the smell or someone in the house was asthmatic. Even some people who used Fish coils reported only burning them when they left the house or while outside due to related respiratory issues. Having screens on windows and doors was reported rarely (19.74%) despite their effectiveness to keep out mosquitos from the home. One individual attributed this to the fact that screening was too expensive. Two health inhibiting preventative practices were reported. The burning of tinder/garbage to prevent mosquitos (29.39%) could be harmful to those who breathe in the fumes or could harm the surrounding environment. One person also reported smoking cigarettes as a preventative practice which could cause harm to the smoker and those around them. It is important to keep in mind smoking is a potential problematic behavior that should be discouraged, but, due to lack of response this may not be a primary area of concern for vector control in Belize.

Regularly cleaning yards (96.93%) was reported as the number one action to eliminate mosquito breeding sites. Turning over containers (62.28%) and cleaning containers that store water (61.40%) were also highly reported among respondents. These practices were conducted weekly or biweekly according to most respondents. Some respondents even reported that their household attempts to remove stagnant water by draining it from the yards (11.84%) or filling in holes that hold water (1.75%). Despite these efforts 8 respondents still reported that stagnant water was a problem for their household (Table 10). A noteworthy preventative practice is that some households bore holes in the bottom of containers (1.32%) to prevent water from settling in containers. Only 3.95% of households treat water with larvicides despite this being a very effective practice. This lack of use can be explained by the fact that larvicides are not available on the public market and only distributed by the MOH and Western Regional Vector Control Unit.

It was a concern to see that 19.74% of respondents put burn/motor oil or Clorox in puddles to prevent mosquitos from breeding. This is a potential hazard to the environment as the run off of the oil and Clorox could contaminate local water bodies. Research assistants also reported that some survey participants, upon being asked if they used oil/Clorox in puddles, responded favorably to this practice despite not having used it. Many voiced that they would begin using this practice to prevent mosquito breeding. Research assistants then had to instruct the participant of the harms that this practice could do to the environment and provide alternatives.

Table 8: Preventative practices against the spread of mosquitos among residents of Belmopan, Belize, 2017

Practice (N=228)	Yes	No
	Number (%)	Number (%)
Preventing mosquito-man contact		
Use mosquito nets	118 (51.75)	110 (48.25)
Burn mosquito coils (Fish)	171 (75)	57 (25)
Use fans	193 (84.65)	35 (15.35)
Use personal mosquito repellant	48 (21.05)	180 (78.95)
Use bug spray (Baygon, Fish, etc.)	105 (46.05)	123 (53.95)
Close doors early (5pm)	148 (64.91)	80 (35.09)
Screen windows and doors	45 (19.74)	183 (80.26)
Use yellow lights	5 (2.19)	223 (97.81)
Wear long pants/shirts/bright clothing	10 (4.39)	218 (95.61)
Use the fire hearth and burn tinder/garbage	67 (29.39)	161 (70.61)
Smoke cigarettes	1 (.44)	235 (99.56)
Eliminating mosquito breeding sites		
Regularly clean yard	221 (96.93)	7 (3.07)
Clean gutters and roof	40 (17.54)	188 (82.46)
Clean containers that store water	140 (61.40)	88 (38.60)
Change water in pots regularly	1 (.44)	227 (99.56)
Turn over containers	142 (62.28)	86 (37.72)
Bore holes in bottom of containers	3 (1.32)	225 (98.68)
Cover water storage containers	9 (3.95)	219 (96.05)
Drain/remove stagnant water	27 (11.84)	201 (88.16)
Fill in yard to prevent stagnant water	4 (1.75)	224 (98.25)
Treat water with larvicides	9 (3.95)	219 (96.05)
Treat home with insecticides	7 (3.07)	221 (96.93)
Put oil/Clorox in puddles	45 (19.74)	183 (80.26)

Tables 9-11 summarize data that was collected upon request of the stakeholders during the first consultation. Data on how the households obtained their mosquito nets and for what reason was particularly important to the MOH (Table 9). The representatives of the MOH said that they had distributed mosquito nets to pregnant women during the outbreak of zika; however, they had not evaluated the impact of the intervention.

According to respondents who used mosquito nets, the majority obtained their nets from a store (74.57%) and only 16.95% received a net from the MOH. Only 14.29% said they had obtained the net due to a pregnancy and only two of these respondents said they had received the net from the MOH. Those who received the nets from the MOH explained that it was due to contracting one of the mosquito-borne diseases. Practically everyone reported that the nets were effective in preventing mosquito bites (99.05%). Occasionally a respondent would mention that nets were not used every night due to it being uncomfortable, too hot, or the net was too old to be effective.

Table 9: Information on mosquito nets used by respondents in Belmopan, Belize, 2017

Variable (N=118)	**Yes**	**No**
	Number (%)	**Number (%)**
Where did you obtain your mosquito net?		
Store	88 (74.57)	30 (25.43)
Hospital	5 (4.24)	113 (95.76)
Ministry of Health	20 (16.95)	98 (83.05)
Homemade	1 (.85)	117 (99.15)
Was the net received due to someone being pregnant?	10 (14.29)	60 (85.71)
Was the net effective in preventing mosquito contact?	104 (99.05)	1 (.95)

Sum of N for some variables may not equal total N due to missing responses

The Western Regional Vector Control Unit personnel mentioned that the practices represented in Table 10 were problems they encountered in the field. Collecting and selling recycling is of concern as these containers can become potential breeding sites for mosquitos, if left in yards. Only 15.35% of respondents said that they collect recycling to resell or use for other purposes. In Belmopan, there is never a lack of water and the water system is checked on a daily basis for contamination. The quality and constant supply of water would eliminate the need for collecting and storing rain water; however, we found that 43.86% of households do in fact conduct this practice. These containers can become breeding sites for mosquitos and other vectors and are a health concern. This is especially true when only 4 (4%) of the 100 households that collect/store water reported also covering these containers to eliminate breeding sites. Finally, 39.03% of respondents reported that stagnant water was a problem for their household.

Collecting and storing water is most likely due to this practice being a part of their culture as we were told by Western Regional Vector Control Unit personnel that there is no need for water collection in the Belmopan area. Unlike in other areas the water supply is clean and constant. It is also possible that with large family sizes water bills can become expensive. Therefore, water collection helps to save some money.

Table 10: Practices and observations that may contribute to mosquito-man contact in Belmopan, Belize, 2017

Practice (N=228)	Number	Percent
Collect/sell recycling		
Yes	35	15.35
No	201	84.65
Collect or store water		
Yes	100	43.86
No	128	56.14
Reports that yard has stagnant water		
Yes	89	39.03
No	139	60.96

Sum of N for some variables may not equal total N due to missing responses

Table 11 expands on the practice of collecting water and storing it because Western Regional Vector Control was interested in why and with what do people collect and store water. The majority of household's use collected/stored water for washing (60%) or cleaning purposes (30%). Water was mostly collected in drums or vats (54.74%) that carry 21-50 gallons of water (59.09%).

Table 11: Further information on water collection and storage practices in Belmopan, Belize, 2017

Variable (N=100)	Number	Percent
Why do you collect/store water		
For flushing	3	3.00
For washing clothes/dishes	61	61.00
For drinking	26	26.00
For plants	15	15.00
For cleaning	30	30.00
For animals	8	8.00
For washing vehicles	5	5.00
What kind of container do you collect/store water in		
Buckets	20	21.05
Drums/buckets	7	7.37
Drums/vats	52	54.74
Tanks	9	9.47
Pilas	5	5.26
Gallons	2	2.11
What size are the containers in gallons		
50+	13	14.77
21-50	52	59.09
10-20	20	22.73
1-10	3	3.41

Table 12: Field observations of households surveyed in Belmopan, Belize, 2017

Variable (N=228)	Number	Percent
Positive practices		
Tires as plant pots	3	1.32
Clean Yard	38	16.67
Covered drain	3	1.32
Drain in yard	12	5.26
Gravel/cement yard	7	3.07
Perceived problem areas		
Latrine	65	28.51
Creek nearby	48	21.05
Empty lots	52	22.81
Overgrown side grass	11	4.82
Absence of a drain	4	1.75
Unkempt yard	2	.88
Live stock	9	3.95
Potential breeding sites		
Banana trees	102	44.74
Recycling in yard	50	21.93
Ponds	8	3.51
Well	39	17.11
Stagnant water	60	26.32
Dirty/watery drain	51	22.37
Pila	36	15.79
Abandoned vehicles/parts	35	15.35
Tires	31	13.60
Containers	47	20.61
Old appliances	20	8.77
Cinder blocks	15	6.58
Abundance of plants	111	48.68
Potential mosquito resting area		
Shade trees	85	37.28
Sheds	20	8.77
Abandoned buildings	2	.88
Metal/wood scraps	29	12.72

Sum of N for some variables may not equal total N due to missing responses

Table 12 summarizes field observations taken of each household that was surveyed. Some of these observations may be underreported due to the fact that researchers were not always able to view the entire property on which the residents resided. Therefore, these observations are recordings of what was visible and stood out to the researchers. Researchers were each given a guide to follow; however, some observations came up that were not included in the guide. Observations are divided into four categories: positive practices, perceived problem areas, potential breeding sites, and potential mosquito resting areas.

Observations under positive practices demonstrated unique or health enhancing behaviors that would reduce or prevent mosquito populations. All 38 households observed to have a clean yard (16.67%) also reported regularly cleaning their yard; however, two households were observed to have unkempt yards (.88%) despite reporting to regularly clean the yard (Table 8). Having a covered drain (1.32%), a drain in the yard (5.26%), or gravel/cement yards (3.07%) were actions perceived to help prevent stagnant water in the yard and keep mosquitos from breeding. Although only 1.32% of respondents were observed to use tires as plant pots, this was deemed a unique way to recycle a container that could be a potential breeding site.

Perceived problem areas were identified by the respondents in the survey and then further observed by the research assistants. Latrines (28.51%) were identified as a place where mosquitos would congregate and possibly breed. Technically, latirnes are not legal to have within city limits. Other areas of concern for respondents were the creeks (21.05%), empty and overgrown lots (22.81%), and overgrown side grass (4.82%). High grass was often perceived as a resting place for mosquitos. In this case many respondents said this was a problem, but it was not their responsibility to cut it. This was the responsibility of the City Council. Others stated that they would cut the side grass despite it not being their problem; however, they expressed reluctance. Respondents also said that overgrown lots and bush areas were a problem, and the City Council should take action by identifying who owns the property and fining them for not taking care of it. Not only are these areas a problem for mosquito breeding but also a problem for providing homes for dangerous wildlife like snakes. Many also informed the research assistants that mosquitos like to rest in any dark areas, especially corners of the house and under beds; however, we were unable to observe these areas.

The greatest concerns for mosquito breeding sites were banana trees (44.74%) and plants that could hold water (48.68%). According to Western Regional Vector Control, a study is currently being conducted with ovi traps in another village near Belmopan. They have found that the greatest number of mosquito larvae are coming from ovi traps near banana trees and other plant material. A total of 21.93% respondents had visible recycling in their yards. Of those observed, 48 (96%) respondents had recycling in their yards despite reporting that they regularly clean their yards. Also 34 (17.61%) people who reported not collecting or selling recycling were observed to have it in their yards. Dirty and watery drains (22.37%) were another problem noted by respondents. They were able to recognize them as potential breeding sites, and, from what the research assistants observed many drains were clogged with trash which could also act as breeding sites. Although perhaps not as problematic for *Aedes* breeding, it has been shown that *Anopheles* mosquitos will breed in drains because stagnant rain water in clogged drains can become very nutritious breeding sites in only several days (Tariq, 2001; Paploski *et.al.,* 2016).

Shade trees (37.28%) were perceived to be the number one resting area for mosquitos in people's yards. These are usually almond trees, coconut trees, or trees that are attractive to mosquitos. Stakeholders and respondents both identified these as problem areas and potential areas where people are more at risk of getting bit by mosquitos. One respondent mentioned that they were often bit by mosquitos while resting in their hammock under these trees. It has also been confirmed that *Aedes* mosquitos will breed in containers that hold leaf litter and are high in nutrients which are usually found beneath shade trees (Hemme et.al., 2009; Getachew et.al., 2015). This will be an interesting problem to address as residents will not respond well if they are forced to cut down their shade trees. Other areas such as sheds (8.77) and scrap piles (12.72) could be areas for mosquitos to escape to during fogging or residual spraying efforts, as these areas may be blocked or forgotten when spraying is conducted.

3.1.5 Government Actions, Perceptions, and Recommendations

City Council and the Western Regional Vector Control Unit partner to fog and spray Belmopan with insecticides. Insecticides used for fogging are Malathion 96% and ICON (Lambda Cyhalothrin 2.5EC). These insecticides have been used since the 1980s and 1990s. Delatamethrin 5% WP has been used for indoor residual spraying since the 1990s. Tables 13 and 14 summarize the response of residents to the government's efforts. Only 85.02% of respondents said that fogging occurred in their area. Although they said it occurs, many only see it happen approximately once a year or very rarely. Those who responded "no" hadn't seen the fogging trucks in a long time or lived off the main road where the trucks did not pass. At the time of surveying the trucks were just starting to pass in some neighborhoods again. Respondents with respiratory issues were more likely to respond that the fogging affected their health (34.92%). Some also reported headaches, agitated allergies, and itchy skin, throat, and eyes. Health issues were reported to be worse if one was walking along the road when the truck passed therefore one respondent recommended a better notice that the truck would be passing. Most simply reported that the fogging has a terrible smell (63.96%) but would go away eventually.

According to the MOH, fogging is most effective for outside areas and is only somewhat effective inside homes if residents keep their windows open as the fogging trucks pass. This allows the chemicals to also get in the homes where many mosquitos will hide during the day. However, 60.91% of respondents reported that they close their doors when the trucks pass rendering the government's actions less effective. Some explained that this was due to asthmatic problems, concerns about breathing in the chemicals, and that spraying occurred during the evening when doors were already closed. Those who open doors and windows or potentially do nothing (21.32%) are more likely to reap the benefits of the fogging, and these respondents usually mentioned that they were informed by the MOH that the insecticides were harmless to humans. Those who believed the fogging

Table 13: Response to government fogging in Belmopan, Belize, 2017

Variable (N=228)	Number	Percent
Does fogging occur in your area?		
Yes	193	85.02
No	34	14.98
Does fogging affect your health?		
Yes	66	34.92
No	123	65.08
Does fogging smell bad?		
Yes	126	63.96
No	71	36.04
Practices done in response to fogging*		
Close doors and windows	120	60.91
Cover food and other materials	43	21.83
Open doors and windows	43	21.32
Do nothing	42	21.32

* N=197
Sum of N for some variables may not equal total N due to missing responses

caused health issues mentioned headaches, asthmatic attacks, itchy skin, and red or itchy eyes. These respondents would normally close their doors and windows.

Fewer respondents reported residual spraying occurring in their homes (74.55%). Sometimes this was due to the health inspectors simply not coming by, health problems, new born children, or general refusal to have their homes sprayed. Some respondents had no idea the MOH conducted this spraying and one respondent said they paid others to spray their home regularly. Of those who had their homes sprayed, 2.23% said they only allowed the spraying to occur outside. Some respondents said they would spray their own homes (1.75%) on a regular basis because they believed it to be very effective.

Table 14: Response to government residual spraying in Belmopan, Belize, 2017

Variable (N=228)	Number	Percent
Has the government sprayed your home with insecticides?		
Yes	167	74.55
No	57	25.45
Do you spray your own home?		
Yes	4	1.75
No	224	98.54
Practices done in response to spraying*		
Cover food, clothes, etc.	161	93.60
Leave the house	134	77.91
Clear out cabinets	35	20.35

*N=172
Sum of N for some variables may not equal total N due to missing responses

Table 15 summarizes the perceptions respondents had in regards to fogging and insecticide spraying. Many found it to be effective (71% and 83.63%). Despite their thoughts that fogging was effective, respondents varied in how effective they thought it actually was. Some mentioned they thought it was effective for a few minutes to a few hours, and others said it was only effective for a few days. It was common for participants to mention that they only thought fogging was effective near the roadside, or for killing mosquitos outside and not in the home. We did receive a few unique perceptions on the fogging efforts. One individual believed it actually attracted more mosquitos, while another believed it was not conducted properly. In fact, one individual also mentioned finding more mosquitos in her home after the fogging occurred. Another participant mentioned that he believed the government was only spraying water and not insecticides. He believed they were only making a show of the fogging.

Of those who found spraying effective, most mentioned it was highly effective for killing spiders or cockroaches. They believed it was less effective or not effective in killing mosquitos. A few respondents mentioned that the mosquitos would return a few days after the spraying had occurred. Finally, one respondent had heard that the health inspectors were not spraying homes but instead selling the insecticides. He did not believe this was in good practice.

Table 15: Perceptions on government actions to reduce mosquito populations in Belmopan, Belize, 2017

Perceptions (N=236)	Yes	No	Maybe	Unsure
	Number (%)	Number (%)	Number (%)	Number (%)
Do you think fogging is effective?	142 (71.00)	42 (21.00)	10 (5.00)	6 (3.00)
Do you think residual spraying is effective?	143 (83.63)	25 (14.62)	2 (1.17)	1 (.58)

Sum of N for some variables may not equal total N due to missing responses

3.1.6 Associations Between Variables

Sociodemographic

A logistic regression to determine if sociodemographic characteristics were associated with knowledge scores (Appendix A). All demographic variables were included in the model except for language and ethnicity because these variables were not tested in similar studies (Shuaib *et.al.*, 2010; Dihmal *et.al.*, 2014; Alyousefi *et.al.*, 2016). Only nine respondents had a knowledge score of 80% or higher therefore, we adapted Bloom's 60% cut-off point for moderate to high proficiency of knowledge to determine whether a respondent had sufficient knowledge of the diseases and mosquito behavior (Bloom *et.al.*, 1956). Only 33.33% of respondents demonstrated a proficient level of knowledge at the 60% cut-off point.

Having a monthly income of 2000 BZE or more (P=0.044); the respondent being employed in the government, as a teacher, as a police officer, as a security guard, or was a student (P=0.009); and the respondent having completed a higher level of education (P=0.006) were all associated with knowledge proficiency. Those with higher income or those who were employed in one of the associated occupations, were more likely to have a higher knowledge proficiency where as those with a higher education were less likely to demonstrate proficiency. Those with a higher education would be hypothesized to have more knowledge due to having access to more education and possibly more resources.

This relationship was explored further using a multiple logistic regression model to analyze respondents' education level and the reported source of information (Appendix B). Respondents with secondary and higher levels of education were more likely to report receiving disease and mosquito information, from a school environment, than those with a primary education (Crude RRR=2.31 and Crude RRR=5.06). Those with no education were significantly less likely to report schools as a source of information (Crude RRR= 0.255). This indicates that schooling does contribute to a respondent's knowledge; however, the quality and extent of that information cannot be determined in this study.

It was also found that 13 participants with higher education reported fewer correct answers to mosquito related questions, one of which reported knowing nothing about mosquitos. Only 17 had heard of zika and chikungunya, and 14 had only heard of malaria. Many respondents only received one point for each category. Of those with higher education, 14 knew one or more symptoms of dengue thus scoring a total of 4 points. This demonstrates that there is a lack of knowledge among those with higher levels of education when it comes to mosquito behaviors, zika, chikungunya, and malaria.

Knowledge proficiency was tested spatially. An ANOVA test was used to compare two logistic models; the one used for knowledge and sociodemographic characteristics; and one with a bivariate smooth of the longitude and latitude coordinates. There was no significant difference between the models (P=0.58), suggesting that the additional coordinate data did not explain additional variance in the model. A map was generated to show the distribution of coordinates based upon knowledge proficiency.

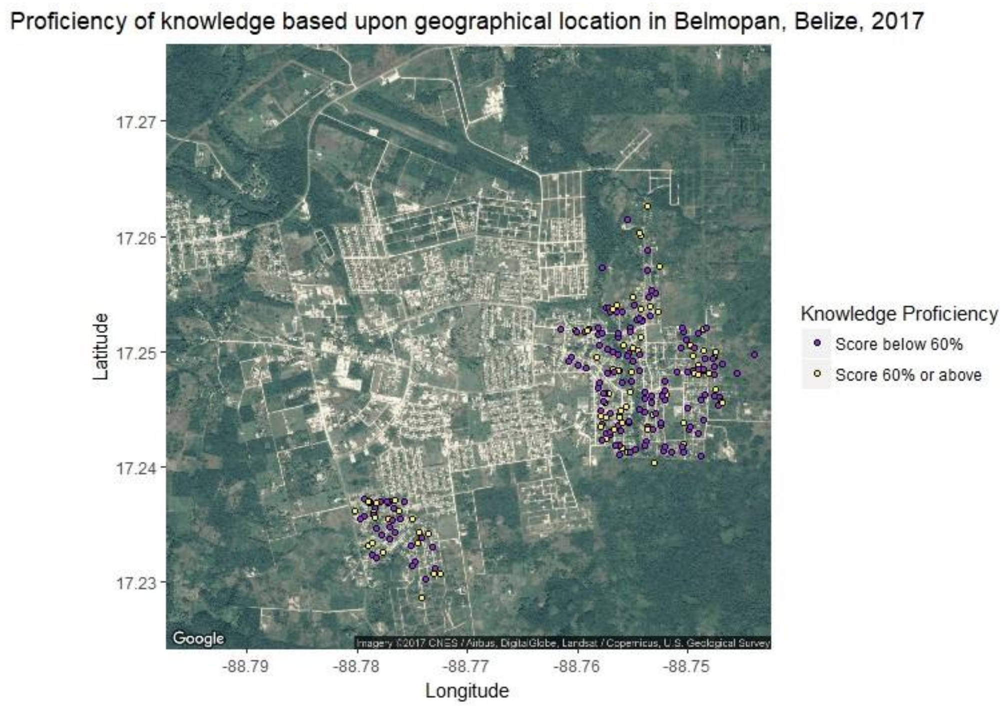


Figure 9: Spatial visualization of knowledge proficiency, in Belmopan, Belize, 2017

Sources and Epidemiology

A logistic regression model was conducted to determine if sources of knowledge and experiences with the diseases were associated with higher knowledge scores (Appendix C). Dengue, zika, chikungunya, malaria, and mosquito sources were combined into single variables. City council sources and having no access to information were omitted from the model because of the low number of responses. Whether the person had contracted a disease, or had a family member who had, was added to the model due to reports of personal experience being a source of information.

If a respondent received information from the MOH they were 4.26 times as likely to demonstrate knowledge proficiency (P=0.011). Respondents who knew a family member who had contracted one or more of the diseases was 3.68 times as likely to demonstrate knowledge proficiency (P=0.023).

Location was found to be significantly associated with whether or not a respondent had contracted one or more of the four diseases (Appendix D). People living in Salvapan were 5.65 times more likely to have contracted one or more of the diseases than those living in San Martin (P=0.038). Maya Mopan residents were 4.62 times as likely to contract a disease however this was not statistically significant (P=0.078). Those living in Las Flores were 7.68 times as likely to contract one or more of the diseases than those respondents living in San Martin (P=0.021). This corresponds to what health inspectors told research assistants about the area and that Las Flores was more likely to have disease transmission than the other three communities. A visual representation is given in Figure 10. Longitude and latitude did not significantly change the model therefore, further analysis was not conducted.

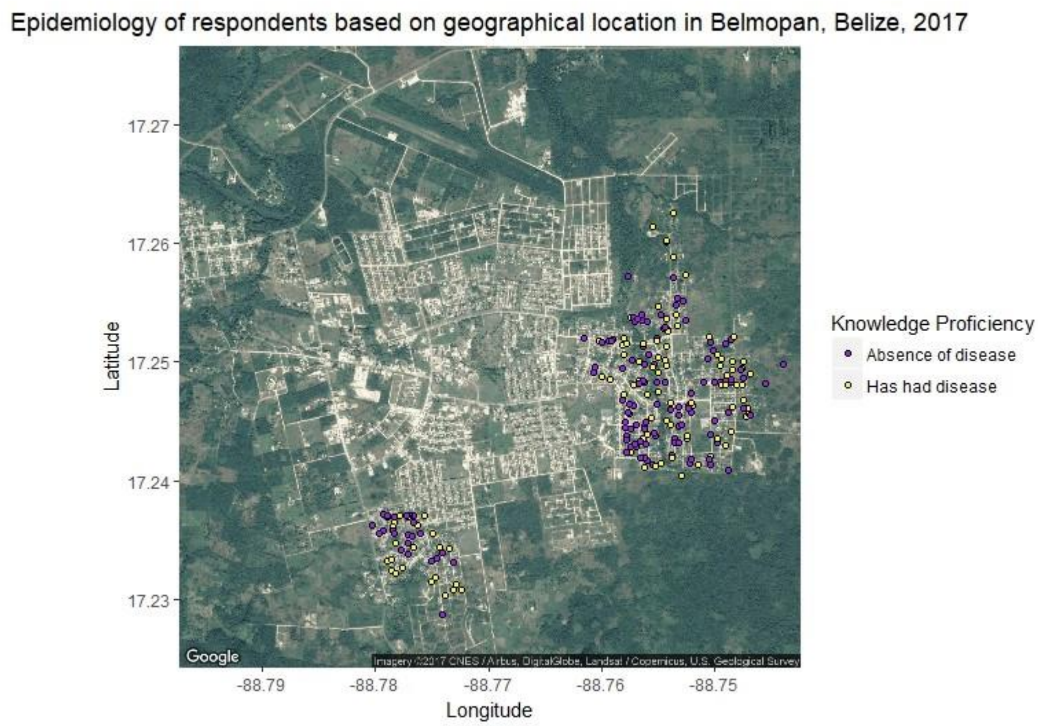


Figure 10: A visualization of respondent epidemiology using GPS coordinates

Practices and Observations

Knowledge proficiency and practices were compared to determine if an association was present. The unadjusted logistic models and models adjusted for location, education, income, and occupation demonstrated no significant associations between knowledge proficiency and practices.

An additional model for mosquito net use was analyzed to determine if there was an association between contracting one of the four diseases and mosquito net use. Those who had contracted one of the four diseases were 3.43 times as likely to have reported using a mosquito net than those who had not contracted one of the four diseases (P=0.02). There is an apparent association between these variables however, causation cannot be determined statistically. It may be hypothesized that causation is present based on further information provided by respondents. Some respondents mentioned that they obtained their nets after they or a family member contracted one of the four diseases. These nets were used to protect themselves and family members from further incidences. Based upon this information and the support from the statistical model, it may be inferred that mosquito net usage is more likely to occur after a member of a household has contracted a disease.

This model was analyzed further with the addition of GPS coordinates. The model, in addition with longitude and latitude, was predicted continuously over space, using a Bayesian generalized additive model with smoothing of the longitude and latitude coordinates. The 'brms' package in the statistical programming language R was used for this analysis. Figure 11 indicates that the likelihood of using a mosquito net increases as distance from the city center increases. To determine if there was a significant spatial effect, an information criterion using leave-one-out cross-validation ("LOOIC") was used to compare models with and without the spatial coordinates. This demonstrated that the addition of coordinate data did not significantly enhance the model for predicting net usage.

Figure 12, maps the standard error of the Bayesian estimates. This map implies that there are higher errors where extreme odds were present. This suggests that the model is sensitive the lower density of data sampling found in these areas. Figures 2, 9, and 10 shows that in the north eastern and eastern most parts of Salvapan and Maya Mopan, where the high standard errors and odds are present, there are fewer coordinates.

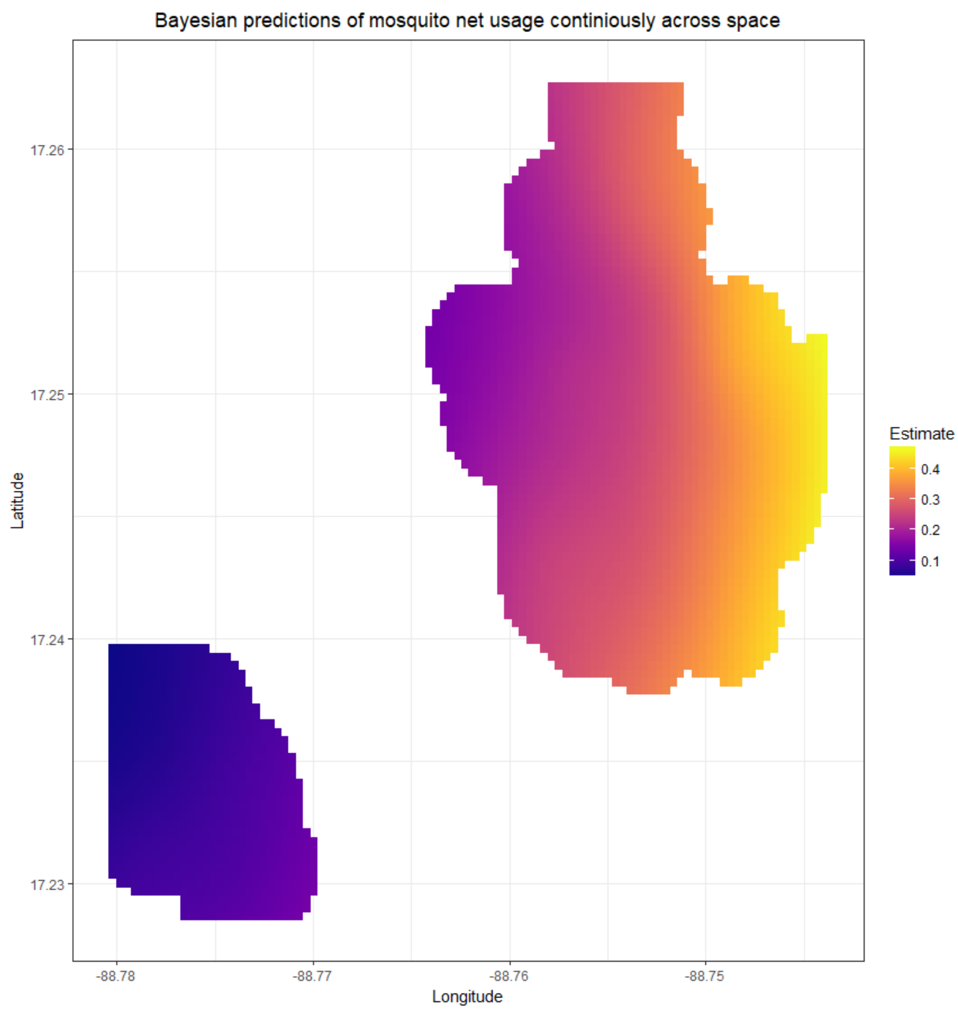


Figure 11: Bayesian spatial model of mosquito net usage in Belmopan, Belize, 2017

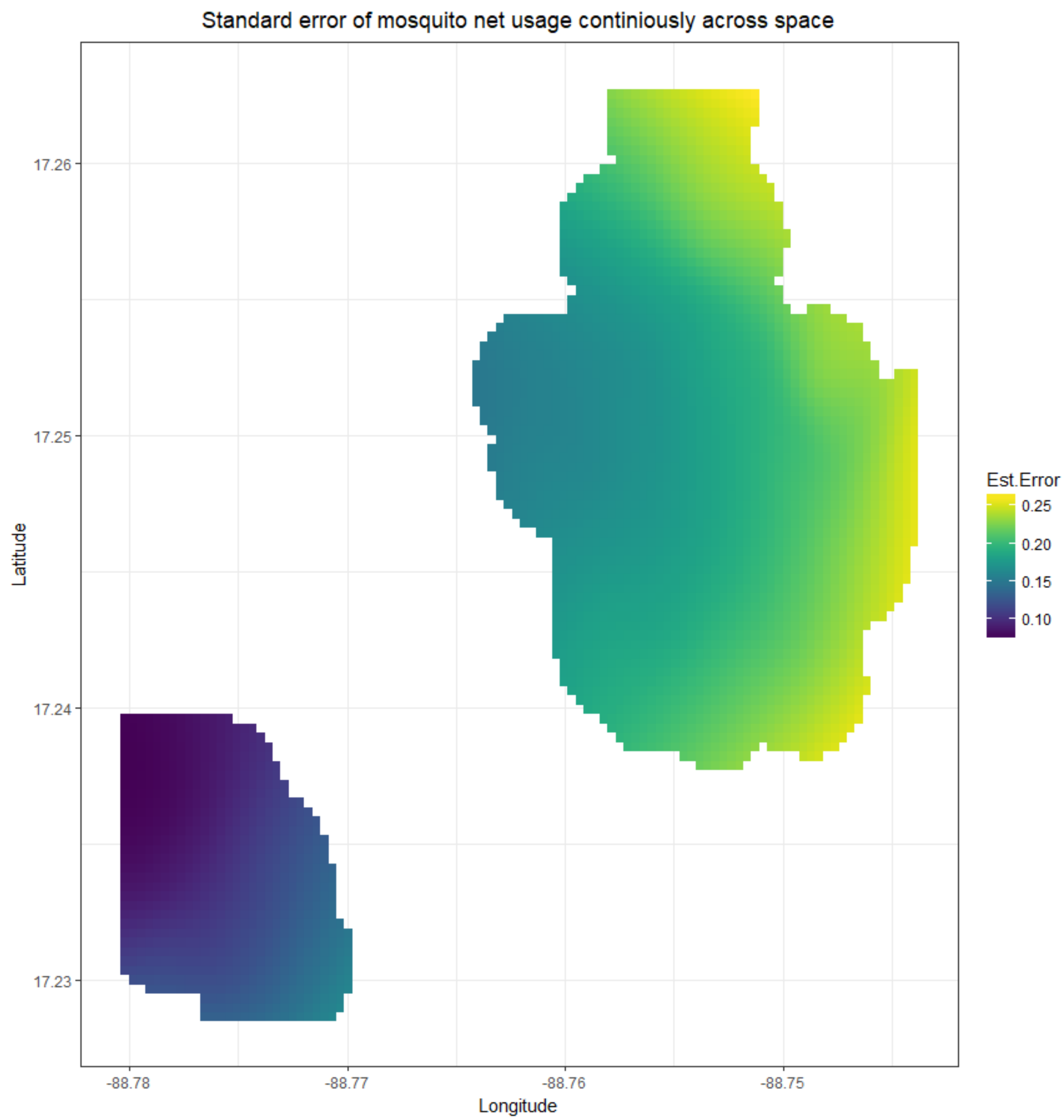


Figure 12: Standard errors of Bayesian model of mosquito net usage and space

Observational data was modeled to determine if there was any association with location. The community used for reference was San Martin. The presence of shade trees, stagnant water, and containers for potential mosquito breeding in yards were all significantly associated with location. Those in Maya Mopan were 25.88 times as likely to have shade trees (P=0.002), 9.81 times as likely to have stagnant water in their yards

(P=0.006). Maya Mopan was the only village associated with the presence of stagnant water in the yard. These increased likelihoods in Maya Mopan may be because of the lack of urbanization in the area. The community is on the outskirts of Belmopan and rapidly expanding into the bush areas. Salvapan residents were 12.94 times as likely to have shade trees (P=0.012) and Las Flores residents were 8.27 times as likely (P=0.043). Maya Mopan, Salvapan, and Las Flores residents were all significantly less likely than residents of San Martin to have containers for mosquito breeding in their yards. These containers include recycling, tires and other containers not used for storing or collecting water. San Martin is the most urbanized community and we were told that trash from the inner Belmopan area will flow down the drains into the community. This might explain the higher concentration of containers in this community compared to the others. These associations may be strongly affected by researcher bias, because of how observations were collected.

3.1.7 Respondent Recommendations

At the end of the survey we asked respondents to give their own recommendations on how to solve the problems the community was facing. Recommendations were coded, using NVIVO 11, to themes associated with key terms (i.e. “drains”, “trash”, “spraying”). Themes were further narrowed into three primary subthemes. Noteworthy recommendations or comments that did not fall under the subthemes was classified as other.

Cleanliness

A lack of cleanliness within the community was a major problem for many respondents. This uncleanliness was attributed to neighbors having dirty yards, garbage in the drains, streets and creeks, overgrown lots, and swampy stagnant areas. The majority of participants had something to say about their neighbors' yards and found this is from where most of their mosquito problems stemmed. In order to solve this problem, they believed their neighbors should be fined if they did not continue to clean their yards, or that they should be informed about the dangers of not cleaning. One respondent said she would tell her neighbors herself to clean their yards but was afraid this would anger her neighbors. Therefore, she and others think this should be addressed by the City Council and MOH.

Research assistants reported in their observations that drains, side streets, and creeks were often filled with garbage and containers that could be possible breeding sites. Respondents also identified that the garbage was a definite issue, not only because of mosquitos but because it was unhygienic and harmful to the environment. Most thought the City Council should take responsibility and regularly clean the drains and streets. One individual discussed a situation in which garbage collection was a problem:

The respondent was told to put his garbage in the street for pick up. This took too long so he decided to burn it himself. The police arrived and told him it was illegal to burn garbage on the street, so he insisted that there should be laws against throwing garbage in the streets as well (Field notes, June 27th, 2017).

Others suggested that community clean-up campaigns should occur often and that the community should begin to take charge and no longer rely on the government. To clean up the creeks, respondents suggested placing signs that state "NO DUMPING" near the creek beds and speaking to those who live near the creeks about alternative areas to dump their garbage. Finally, a few people mentioned that dogs increased the garbage problem by spreading it around the street and to other homes. No solutions were suggested to take care of this issue.

Overgrown lots and swampy areas were perceived to be prime areas for mosquito breeding and stagnant water collection. Some households had more problems with this as they were surrounded on both sides by overgrown and bushy areas. Overgrown side grass, swamps, and unkempt parks were said to be the responsibility of the City Council and that the City should come more often, especially in the rainy season, to clean these areas and remove stagnant water. Empty lots were more difficult to address. Respondents believed *"the City should find the lot owners and force them to clean the lots"* (Field notes, June 2017). If the lots were not cleaned, then the owner should be fined. Not only are these lots a problem for mosquitos, they also bring snakes and other unwanted wildlife.

Information

People had mix responses on whether information was a priority. Some believed that the community had a sufficient capacity for knowledge but were ignorant and refused to conduct proper practices. Others thought the City was already doing an adequate job. Despite this, most respondents had suggestions on the delivery of information and the subject and quality of information that was being given.

The way in which information is being delivered brought about many responses. The most innovative suggestion to improve delivery was to begin using social media. One respondent emphasized that almost everyone uses *Facebook, Snap Chat,* or *Twitter*. These would be good outlets to get information to the people quickly and efficiently. The most voiced suggestion was for more house visits to be conducted. Not only would this show that the authorities care about the community, but this may be a better way to deliver information to those far from the city center or who are illiterate. An alternative to house visits was to hold community meetings on these subjects. Respondents also mentioned that more pamphlets should be given out and that more information should be announced on TV and radio stations. One individual said that "*almost everyone listens to the radio at some point*" so the information would reach more people (Field notes, June 27th, 2017). People also thought "*posters should be posted across town on lamp posts, in parks, on basketball courts*," and other public areas (Field notes, July 10th, 2017). The reasoning behind this was because people sometimes learn more from what they see rather than from what they hear. Finally, some respondents mentioned that "*educating children about the issues was very important and that starting young may be beneficial*" (Field notes, June 2017).

Overall people wanted to know more about mosquitos and precautions that can be taken to protect oneself. Very few reported wanting more information on the diseases. However, most did have something to say about the quality of information being delivered. Respondents believed that better teaching methods and "proper" information should be given. They did not provide further explanation about what this meant exactly. Others simply wanted the information explained further which could be done with home visits or counseling. Pamphlets were also said to be difficult to read or had too much information. An example of a zika and dengue pamphlet are provided in Appendix A. It was perceived that more individuals would be inclined to read these pamphlets if more pictures were utilized. It was also important for the respondents to have the pamphlets translated to Mayan or read to them as many were illiterate.

Insecticide use

It was common for participants to want to see more fogging or residual spraying conducted in the community. Answers ranged from having the truck pass every evening, every week, or once or twice a month. Some simply wanted City Council to start earlier in the year or conduct the fogging all year round. They also voiced that the trucks should spray off the main roads, more in the bush areas, and pass by at a slower pace as this would be a more effective use of the insecticides. To increase the effectiveness of the efforts, people thought that better insecticides should be used and that larvicides should be made available to the public to be used in stagnant water. It was interesting to find that many respondents desired an increase in insecticide related efforts despite voicing their concerns about its ineffectiveness to address the mosquito problem and possible harms it could do to the environment.

Other themes

A few areas of concern were brought up that did not fit into specific themes. Drains were a common issue all around. Perhaps there was no drain present on the street or it was unkempt and clogged. Most respondents desired that the City Council come and fix these drains because they would cause flooding of homes and the surrounding area. One individual even stated that the drain on his street had not been fixed in the past twelve years. Respondents also voiced that they wanted mosquito nets to be provided to the community as these were expensive and hard to find. One individual also wanted woodlice to be made available to the community for burning, as he thought this was effective in keeping away mosquitos. Overall people had very constructive and plausible recommendations. Many voiced that they thought the government was doing an adequate job but could make some minor improvements. Others were harsher in their reviews and thought that the government wasn't doing their jobs properly or efficiently. Commonly, however, there was a strong desire for the community to begin working hand in hand to address their own problems.

3.1.8 Administrative Analysis and Observations

There were five main stakeholder organizations that were identified and invited for consultation on the project. Table 16 is a matrix that summarizes their overall commitment and goals in regards to the current project. It was also important to observe more closely and analyze the activities that are already being conducted by these organizations, so that recommendations can be further aligned with stakeholder actions.

Ministry of Health

The Ministry of Health involves three important departments that relate to the current project; the Vector Control Unit, The Health Education and Community Participation Bureau (HECOPAB), and the Epidemiology Unit. The MOH also has a small ethical review board that had to approve our study for the release of data. The Vector Control Unit was our primary connection with the MOH. They have one technical officer that oversees all nationwide activities and 60 additional officers dispersed across the country, working at the regional and district levels. The technical officer helps to develop national strategic strategies and approves research and implementation of efforts. HECOPAB is the health education branch of the MOH and works closely with the Vector Control Unit. They also have regional and district representatives and are in charge of developing health education programs and trainings of Community Health Workers (CHWs). The Epidemiology Unit collects and analyzes data, has access to the Belize Health Information System (BHIS), and were helpful in providing secondary data for the project.

The Vector Control Unit technical officer acted as an important gatekeeper into working with regional and district managers as well as working with other organizations. He explained to us that there are multiple partnerships and MOUs established nationally and internationally in regards to vector control. Nationally they work with other ministries to expand their efforts. For example, they partner with the Ministry of Education to develop a curriculum about mosquitos and the diseases they carry. This curriculum will be established within the next year. The MOH also partners with the University of Belize and City Council for multiple projects. Their international partners include Mexico and Trinidad laboratories, the CDC, PAHO/WHO, and the University of Notre Dame. Their connections to Mexico and Trinidad are very important because blood samples are sent to these locations to be tested for dengue, zika, and chikungunya. Belize does not have a PCR lab of their own to conduct this testing; however, with the help of the CDC and the University of Notre Dame, a lab should be established within the next year. This lack of facilities has greatly reduced their ability to have efficient and swift surveillance of possible outbreaks. They are also working closely with these organizations to test insecticide resistance.

Vector control has conducted multiple interventions within this study's target communities and nationally. A major issue they have encountered is actually evaluating the impact of these interventions. For example, the MOH distributed mosquito nets during the zika outbreaks; however, they were never able to follow up and determine if the women were actually using these nets or how many were even given out. The technical officer told us the MOH simply lacks the capacity and resources to carry out impact evaluation on most of their interventions. He is also concerned that many interventions are no longer effective due to lack of involvement in the communities. Clean up campaigns have been carried out in the northern regions of Belize but the only participants are the government officials. The MOH has also found that many individuals are no longer receptive to information given out through community health workers

(CHWs) or other outlets. The technical officer also emphasized that stakeholder partnerships have been established in the past; however, due to poor supervision and confusion of leadership these partnerships failed.

The MOH technical officer provided additional feedback on their goals for the outcome of this project. Firstly, they hope to use it as a pilot study that will align with the national strategic plans and projects being conducted by the University of Notre Dame. Most importantly, they hope that it can help to establish a sustainable task force that can tackle vector control issues. It was said during the consultations that someone needs to take charge of a dedicated task force that involves the multiple stakeholder organizations. According to the technical officer, the MOH cannot carry this responsibility, despite voiced opinions from the University of Belize that the MOH should take charge. This is due to the lack of resources and time that the MOH can provide. The technical officer also voiced that this task should be taken on by an individual from one of the other stakeholder organizations, more specifically UB. UB representatives believed that this task should not be taken on by one individual but an entire organization. A consensus was not made but the possibility of an MOU was further discussed. Overall the MOH had high hopes for the project outcomes and was very receptive and cooperative with providing feedback and cooperation.

Western Regional Vector Control

The Western Regional Vector Control Unit likely had the highest involvement, impact, and interest in the current study. As the implementing arm of the MOH, they take care of the Cayo district which includes one city, three towns, and forty-one villages. They have a total of 12 personnel, two of which are managers that are responsible for implementation. Only one of these personnel is directly in charge of Belmopan and surrounding area. Their duties involve, premises inspections, residual spraying, fogging, entomological data collection, malaria testing, information dissemination, destruction of breeding sites, conducting food handler trainings and more. The Western Regional Vector Control also focuses on other vector diseases like Chagas disease.

The primary barriers to vector control efforts is the lack of human resources and funding. Many times tasks must be prioritized due to lack of time and too many responsibilities. For example, inspectors are supposed to check cemeteries for stagnant water every few weeks however these usually go unchecked as they are not the highest priority. We were also informed that the two vehicles used for transportation are used by multiple departments but there are only two available drivers. If one driver becomes sick the other must take on part of his responsibilities and put his own aside. This means that certain vector control tasks may not be conducted during that time and the inspector then falls behind. Premises inspections are also conducted by the inspectors. They will receive an alert through the BHIS that informs them of a possible diagnosis of a vector-borne disease. They then locate the patient through their BHIS records and make a home inspection. This has many of its own issues as some people live in the bush and don't have a physical address, or the hospital attendant does not enter the address correctly or validate it with the patient. It can take a lot of time to track down these cases and sometimes they fail to find the patient at all. The inspectors have also had incidences where a single doctor will over diagnose a vector-borne disease and then the inspector may waste valuable time making an unnecessary home visit. We were also informed that after a home visit there is supposed to be a three month follow up visit. Yet again, lack of time and resources means that these follow ups are seldom conducted.

Some of our own observations confirmed and brought to light other barriers for vector control. In 2017 funding was reduced and they were only able to fog once; however, we were told that complete fogging and inspections usually occur twice a year. Upon review of the entomological data we found that complete coverage of communities in Belmopan usually only happened once a year for the past five years. There would be instances where a community would be visited twice or more, but it would only be partially covered. We were told that it was possible that during those years other communities took priority or an outbreak would occur that would call away personnel. Systematic data and insecticide coverage proved difficult due to lack of resources. It was also found that the data collected by inspectors was not systematically reported. Individual inspector reports sometimes varied, and then the manager had to find a way to report the data to his own supervisors. This manager also informed us that local servers and flash drives the data was stored on had been corrupted by viruses and some of the data had been lost. Paper ledgers were the most efficient source for storing all the necessary entomological data for the current study but the year 2015 was missing. Data was only sent through emails and there was no common data base that all interested parties could access. Many times, this data collection was of low priority and most inspectors and managers would lack time to properly collect and organize it all.

The Western Regional Vector Control Unit was very receptive and helpful in assisting with the current study. They hoped that our efforts could provide them with the data necessary to better address their efforts. It was made known that the stakeholders feel that they need to start addressing their efforts to the most at-risk areas and adapt to the current problems, so that resources can be maximized. Many outcomes of the study will address their needs and goals.

City Council

The City Council is most influential among the residents of Belmopan out of all the stakeholder organizations involved. They take care of the public areas, street maintenance, public campaigns, and help establish and enforce city law and policy. Their main goal is to have a clean and healthy environment for residents and hope the project can assist them in these endeavors. They have partnerships with Western Regional Vector Control and are making more partnerships with UB on other projects.

According to the City Council representative, there are some concerns they hope the project can address. They are very interested in how they can become more involved in efforts. Currently, they provide personnel and the Ultra-Low volume truck for the fogging done within the city; however, they are not very involved in other efforts. Their current interest is how to clean the environment of the city to ensure that people stay healthy. This is especially true for public areas like parks and creeks. Along these same lines, there was a desire to find ways that the community would take charge of the environmental issues occurring in the city such as overgrown side grass. Although this is the City Council's responsibility, their resources seem to be stretched thin especially because of the urban growth and development the city is going through. It was also suggested that issues cannot be addressed appropriately and efficiently because many citizens do not pay their taxes. Therefore, the quality and frequency of city efforts declines due to lack of funding. If the community would assist in other ways by coming together perhaps more environmental issues could be addressed. A secondary goal is that they hope to become more involved in information dissemination. Their representative was very adamant about making the findings of the project available to the public and finding better ways to get the information into the homes.

While surveying was conducted further observations were taken into account. As we surveyed farther from the city center it appeared that the efforts of the City Council were not reaching the households and cleanliness, drainage, and other issues became more apparent. This could partially be attributed to the rapid growth and development of Belmopan. We also found that many public parks were overgrown and abandoned. Residents made complaints about such areas and also said these overgrown parks attracted illegal activities. Also, further from the city center we found that there was less access to roads and less enforcement of laws. When discussed during the consultation this again was attributed to lack of funding and resources to address these problems. Also, laws were said to be difficult to enforce due to the laws' unpopularity, possibilities of exploitation of citizens, and lack of compliance by those fined. Overall the City Council was receptive to the project and outcomes, and hoped to become more involved in future efforts.

University of Belize

The University of Belize is a major part of the community as they bring a lot of revenue and people from all over the country to Belmopan. The University is very invested in providing research and internship opportunities for their students and working closely with Belmopan organizations in order to carry out projects. Individual departments however have their own resources and projects which can enhance or inhibit partnerships which depends on the alignment of goals between departments.

Currently UB has conducted research in vector control related projects. They have completed some knowledge, attitude, and perception data on dengue fever. They also have partnerships with the University of Notre Dame to research entomological related topics. Where UB seems to run into issues is sticking with projects and partnerships. This may be due to changes in administration or lack of supervision of the projects. For example, many Belmopan residents identified UB property to be an issue in contributing to the mosquito problems. UB representatives said that they had been attempting to address this by planting mosquito repellent plants on the campus. The MOH further informed us that UB was unable to provide appropriate times for fogging and spraying to occur on the campus. Training had also been conducted by the MOH for UB personnel to carry out these tasks, but, after the initial training there was no further implementation.

This lack of implementation was attributed to losing contact with the staff member in charge. Overall, UB has a lot to offer and can provide many human resources, such as willing students, to assist in future efforts.

ISCR

The Institute for Social and Cultural Research (ISCR) is part of the larger organization the National Institute of Culture and History (NICH). Their role in the project is to ensure that all activities are being conducted ethically and in the best interest of the community, as they are in charge of the local IRB. They were most interested in how we would build capacity of the community to conduct and participate in research. The organization's representative was very receptive to the consultations, the hiring and training of UB students as research assistants, and the plan for dissemination of results. Some additional information resources were made available through the organization.

Table 16: Stakeholder analysis matrix for Belmopan, Belize, 2017

Stakeholder Organization	Involvement in issue	Interest in issue	Influence/power	Resources	Position	Impact of issue
Ministry of Health	Nationwide implementer of control and surveillance programs that are in line with national strategic plans and polices. Carry out health training and health education.	*High*: Desire the project to align with current research and the national strategic plan. Very interested in creating long term partnerships with other stakeholders. Desire to use this study as a pilot to guide future vector control efforts.	*High*: Responsible for all major health data collection and processing. High influence over policy changes but lower influence at ground level. Key gate keeper in making connections with other ministries and organizations.	Surveillance and epidemiological data collections. Funding for some human resources and student interns. Low human resources for vector control.	*Promotor*: Outcomes can help evaluate and influence current vector control efforts and they have strong power in implementing recommendations.	*High*: The outcomes of the assessment will guide vector control efforts for the future and possible influence the establishment of a task force.
Western Regional Vector Control	Carry out all vector control efforts in the Cayo district, including Belmopan. Work closely with other regional health partners to carry out efforts.	*High:* Desire to understand the impact of their current efforts and how to better use their limited resources in targeting the most at risk areas	*High*: As the implementing arm of the MOH, they ensure that vector control strategies are carried out in the communities.	Limited human resources as there are only 12 vector control personnel for the entire district.	*Promotor*: High investment and influence of the project outcomes with the ability to carry out recommendations at the community level.	*High*: Outcomes of the assessment will directly impact their efforts within the community.

			High influencer within the district but low influencer of policy.	Limited funding prevents them from carrying out designated tasks		
City Council	In charge of maintaining a clean and health Belmopan. Assist in fogging efforts taken within the city.	*High:* Desire information on how to achieve a cleaner and healthier environment for citizens. Wants to make strong connections with other stakeholders within the community in order to work toward common goals.	*High*: Has power among the community with the ability to influence and implement community wide campaigns. High influence over city policy and laws.	Average funding and human resources. Most seems to be directed toward other areas that are not involved in vector control.	*Promotor*: Has a high investment in the outcomes and can implement changes at the city and community level.	*High*: Outcomes may influence how involved the Council becomes in future vector control efforts add may help determine their priority targets for health promotion.
University of Belize	Large contributor to Belmopan's population. Conduct research within the community and involved in	*Medium/High:* Desire students to have a greater exposure to public health and in research.	*Medium*: High influence over the student body but only some power in implementing city wide efforts.	Moderate funding possibilities but have many human resources in regards to the	*Defender*: They have a high investment in partnerships and outcomes but have lower possibilities of	*Medium*: Outcomes could help the university become more involved in research,

	environmental/health/ biological efforts.	Would like to work with and give back to the community by creating stronger partnerships.		student population.	directly impacting implementation.	internship, and job opportunities. Will also help increase their community presence.
Institute of Social and Cultural Research	Monitor and promotor of research and development in Belize.	*Moderate*: Desire to strengthen the capacity and quality of research done in Belize. Increase the involvement of Belizeans in research efforts.	*Moderate*: Has the power to approve research and influence how it is conducted but has low influence over vector control efforts.	Informational resources are high but they do not have much funding or human resources.	*Latent*: the outcomes do not directly affect their organization but they ensure that the project is conducted ethically.	*Low*: The use of capacity strengthening by employing Belizeans and community participation fulfills their goals. Outcomes do not directly influence their efforts.

Premises Inspections

As part of the project we had the opportunity to shadow a few premises inspections conducted by the Western Regional Vector Control officers. About six people accompanied us on the inspections, but only one or two would actively take part in the inspection. The inspectors would arrive at the home and introduce themselves to whomever was available. They would confirm that they could inspect the property and give them some information as to why the inspection was to take place. The inspector then walked around the property inspecting any container that may contain water. A positive container was recorded on his data sheet and was dubbed positive if it contained larvae (Appendix B). He informed us that *Anopheles* stay parallel to the water's surface while *Aedes* and *Culex* stay at a 45-degree angle, at the larval stage. He also said *Aedes* will move downwards when the water is agitated but you cannot determine the species of *Aedes* by the larvae. Data is not collected on the type of larvae that is identified. Also, during one of the drum inspections, we observed an *A. aegypti* mosquito land on the surface of the water.

If a container is deemed positive, the inspector either turns over the container to displace the water or uses a larvicide. Any container that contains water is turned over whether positive or not. They use two types of larvicides: Altosid XR – methoprene (since 2012), Temephos 1% granular abate (since 1980's), Temephos 44% Liquid (since 1990's), and Natular DT (since 2010). The Temephos granular abate is a tablet put in drums that, when dissolved, creates a film over the water to suffocate the larvae. The Natular DT is a powder that works similarly but is safe to drink. This works for about 60 days. However, it was brought to our attention that the female mosquitos may be able to detect the larvicide and look for non-treated containers in which to lay their eggs. If a container cannot be treated or turned over, a member of the household is informed on how to clean it properly.

At the end of the inspection the inspector talks to the household members about mosquitos and the diseases they carry and precautions that should be taken. They will also give the members some fliers, if deemed necessary. The inspector said that he will instruct the members to put sardines in wells and strive to use biological methods to destroy larvae or simply cover containers that collect water. If anyone in the household is exhibiting symptoms of malaria then the inspector will take a blood smear for testing. Supposedly they haven't had a case of malaria in the area for four years. The household members will also be instructed to go to the hospital to seek treatment if they show signs and symptoms of any of the diseases.

After all the houses were inspected, the inspector provided us with some further information. The inspector informed us that biological methods are the best way to control the larvae. This can mean using fish or allowing water roaches, dragonfly larvae, and *Toxorhynchites* mosquito larvae to flourish in containers as all these species eat the other mosquito larvae and are not harmful to people. He also said that despite fogging's effectiveness it should not be conducted daily as the life cycle of the mosquito takes about 7-10 days. Therefore, it is most effective once a week or every two weeks when the next adults are emerging. We were also informed that the public health inspectors are in charge of businesses while the vector control officials are in charge of homes and dwellings.

The inspectors also made it clear how difficult their jobs were to conduct with a lack of resources and time. They are normally required to conduct 25-30 house visits a day. They say this is extremely difficult with the amount of time it takes to conduct each visit and other issues such as rain can prevent them from achieving this number. The research assistance expressed that this required number of households was outrageous as it was difficult even for them, while conducting surveys, to visit 15 households on a good day. This was also without having to thoroughly inspect the house but still having a 20 to 40-minute conversation with the household members. The inspectors also mentioned that if government revenue is low then they will not be able to do their jobs or will only visit houses if there are multiple cases of disease. They also find themselves returning to the same houses as people refuse to start changing their practices.

We took some additional observations and notes during the inspections. Research assistants mentioned that the household members were more responsive to the inspectors than to us, while doing surveys. This was attributed to the fact that the people likely trust the inspectors more so than students, and the people know why the inspectors come as they see them throughout the community. Research assistants also mentioned that being able to observe the whole home would have greatly benefitted our own study. It was also noted that inspectors may conduct their inspections in slightly different ways. The inspector we shadowed did the inspection himself and then returned to the household member to give them information. Another inspector informed us that he will take the member around the home, instructing them while they walk, and actually have the resident apply the larvicides. He believed that this allowed the people to take ownership of the problem.

Finally, the research assistants asked the inspector in what ways volunteers could help with the control efforts. He told us that *"he thinks premises inspections can be conducted by minimally trained volunteers"*. This is especially true when it comes to treating and looking for positive containers as this requires little to no skills. If the volunteers were instructed with the right information they may also be useful in talking to the members of the home about preventive measures and mosquitos. He expressed that this would allow for more inspections to occur and perhaps let the people take more control over the issues plaguing their community. The research assistants expressed that UB students may be the solution to their human resource problem. Overall the inspections were very informative and helpful in understanding more thoroughly how practices are implemented in the community.

3.2 Secondary Data Collection

3.2.1 Entomological Data

During premises inspections, the data collected is processed and used to report the household index (HI), container index (CI), and Breteau index (BI) for the given area. These indices are reported to the Ministry of Health. Due to the lack of systematic coverage and loss of data, indices for our target populations were occasionally incomplete.

The data for 2015 was missing in electronic and paper formats. No data was collected in the central Belmopan area because vector control efforts only target the most at-risk locations.

Figures 13, 14, and 15 reports, by index, the level of risk of each community from 2012 to 2016. The year 2012 was included because 2015 data was missing, and to understand the change of risk over time, more data was needed. High infestation is categorized by any index level five or above and low risk is any index below five. These are the universal thresholds defined by the WHO (Who, 2009). Data was missing for Maya Mopan in 2013, and Las Flores and Salvapan in 2012, for all indices. BI was missing for Salvapan and San Martin in 2014. Two complete cycles were conducted in Las Flores for 2014. The averages of these two cycles were used to report infestation levels.

Figure 13 reports the level of infestation based on household indices for the target communities. HI is the percentage of households inspected that have larvae or pupae (Who, 2009). Levels of infestation appear to have started low for the communities in 2012 and 2013 with greater levels of infestation in 2014 and 2016. All communities reported a high infestation for 2016.

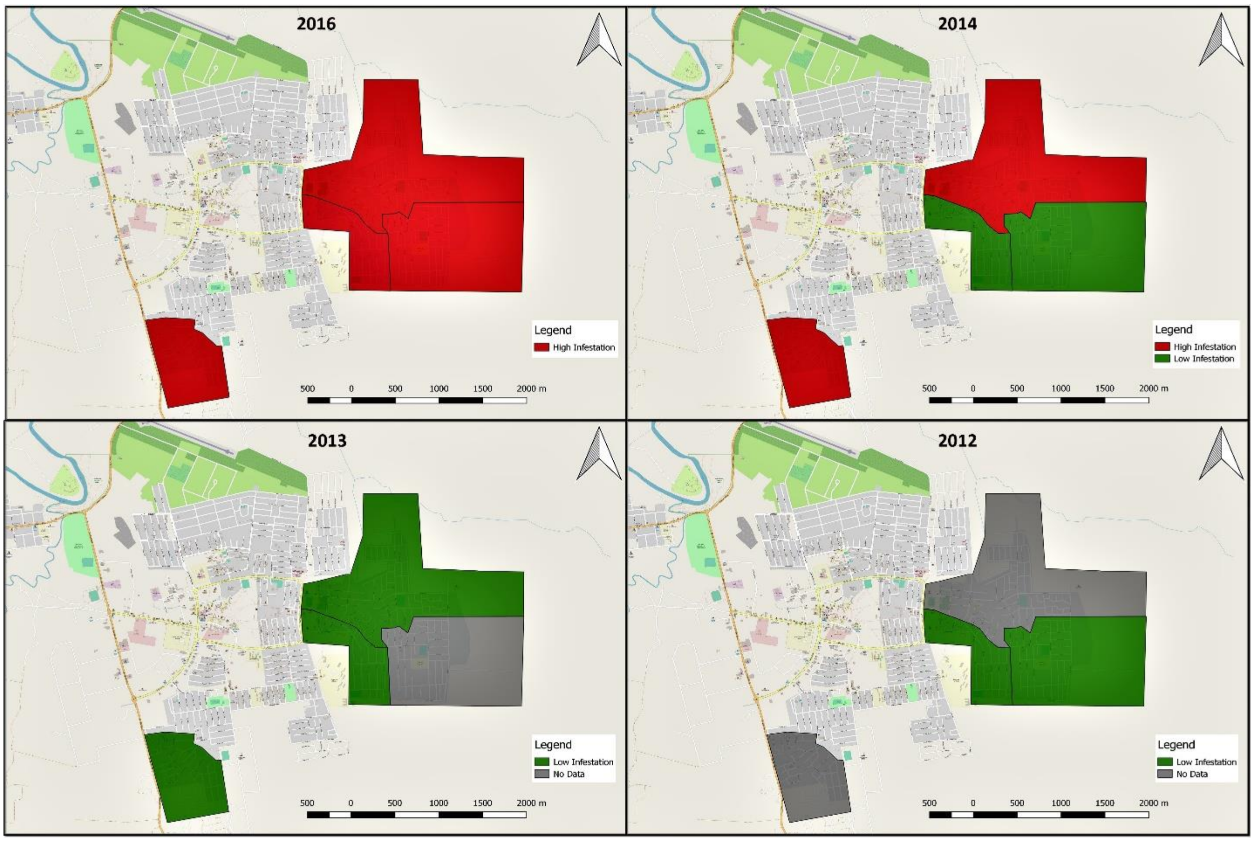


Figure 13: Household indices for communities in Belmopan, Belize, 2016-2012

Figure 14 reports the level of infestation based on the Breteau index reports. This is the percentage of positive containers per 100 households inspected (Who, 2009). More data is missing for this index than the other two indices. Levels stay relatively low from 2012 to 2014 with a transition to high infestation for Las Flores in 2014. In the year 2016, all communities reported a high level of infestation.

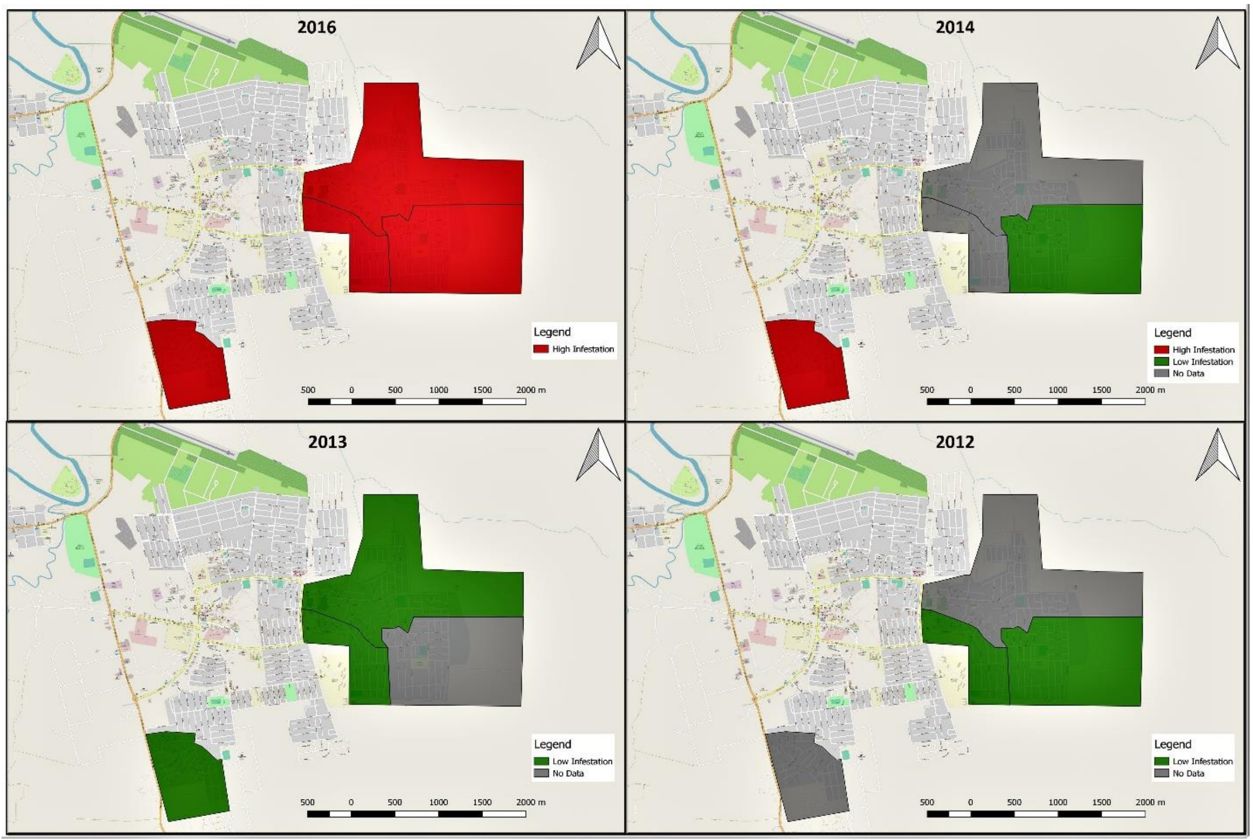


Figure 14: Breteau indices for communities in Belmopan, Belize, 2016-2012

Figure 15 reports the level of infestation based on container indices. This index reports the percentage of wet containers that tested positive for larvae or pupae (Who, 2009). Level of infestation is high for almost all years, in all communities, with a drop-in infestation in 2013. This index is not regularly used by the Western Regional Vector Control Unit however it is still reported. In fact, entomological data is rarely used to influence efforts instead the Western Regional Vector Control focuses on epidemiological data.

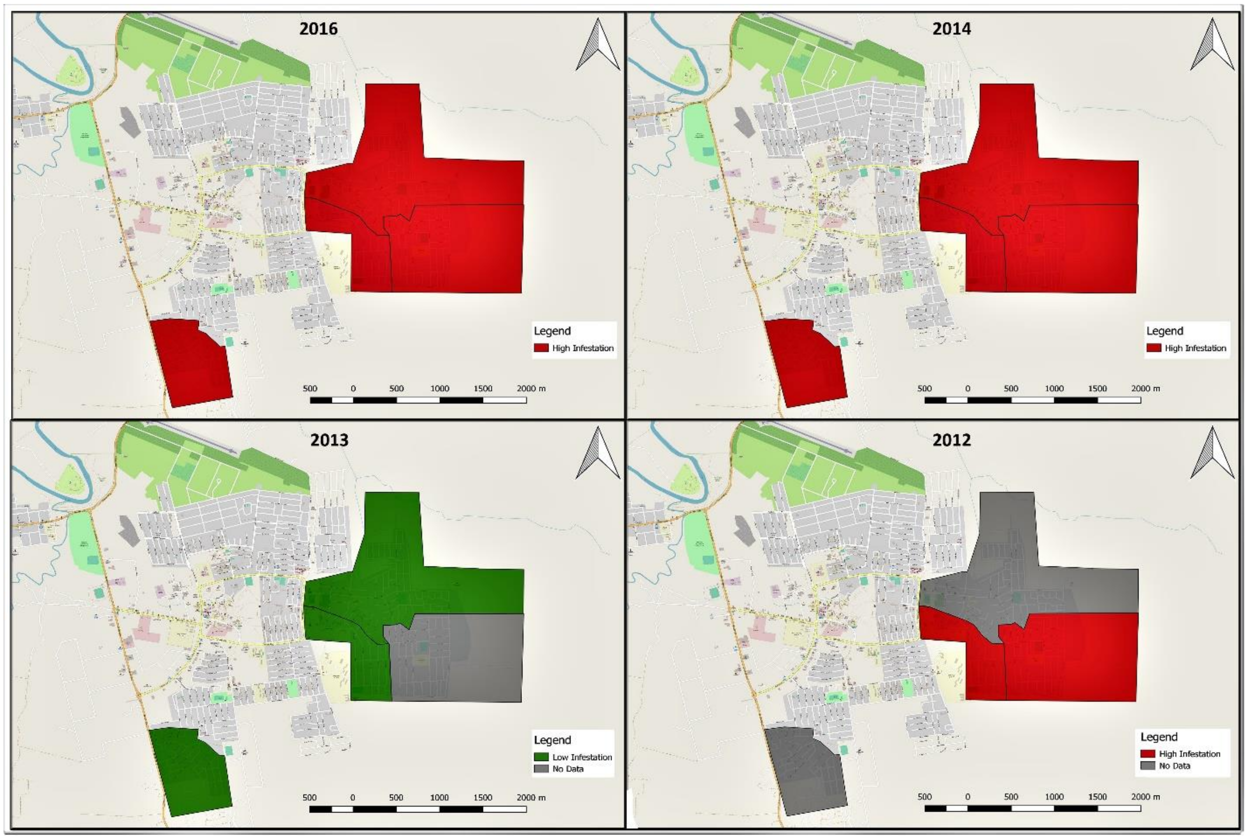


Figure 15: Container indices for communities in Belmopan, Belize, 2016-2012

Figure 16 reports the index measures for all communities from 2012 to 2016. In Maya Mopan, all indices start below five, in 2012, except for the container index. Then in 2014, the indices drop from where they started in 2012. By 2016, there is a large jump in the reported indices. In San Martin, there is a similar pattern. There is a drop in the reported indices in 2013 from where they started in 2012. Then from 2013 to 2016 there is a steady increase in percentages. In 2016 the household and Breteau indices are reported just slightly above the threshold while the container index almost reaches 15 percent. In Las Flores, there is a steady increase in the index percentages from 2013 to 2016. This is the only community where data collection and vector control efforts were completed twice in one year. The first cycle was completed between July and September and the second was conducted in October. Index percentages for HI and BI were 6.39 and 7.83. These are the lower points on the reported graphs for 2014. By October the percentages had increased to 15 and 20.8 percent. The CI percentage actually decreased between cycles from 8.3 to 5.94. The first cycle is the higher point on the reported CI graph for 2014. In 2016, the HI and BI percentages stayed almost the same as in 2014 while the CI percentage increased. Salvapan shows a steady increase for all indices from 2013 to 2016.

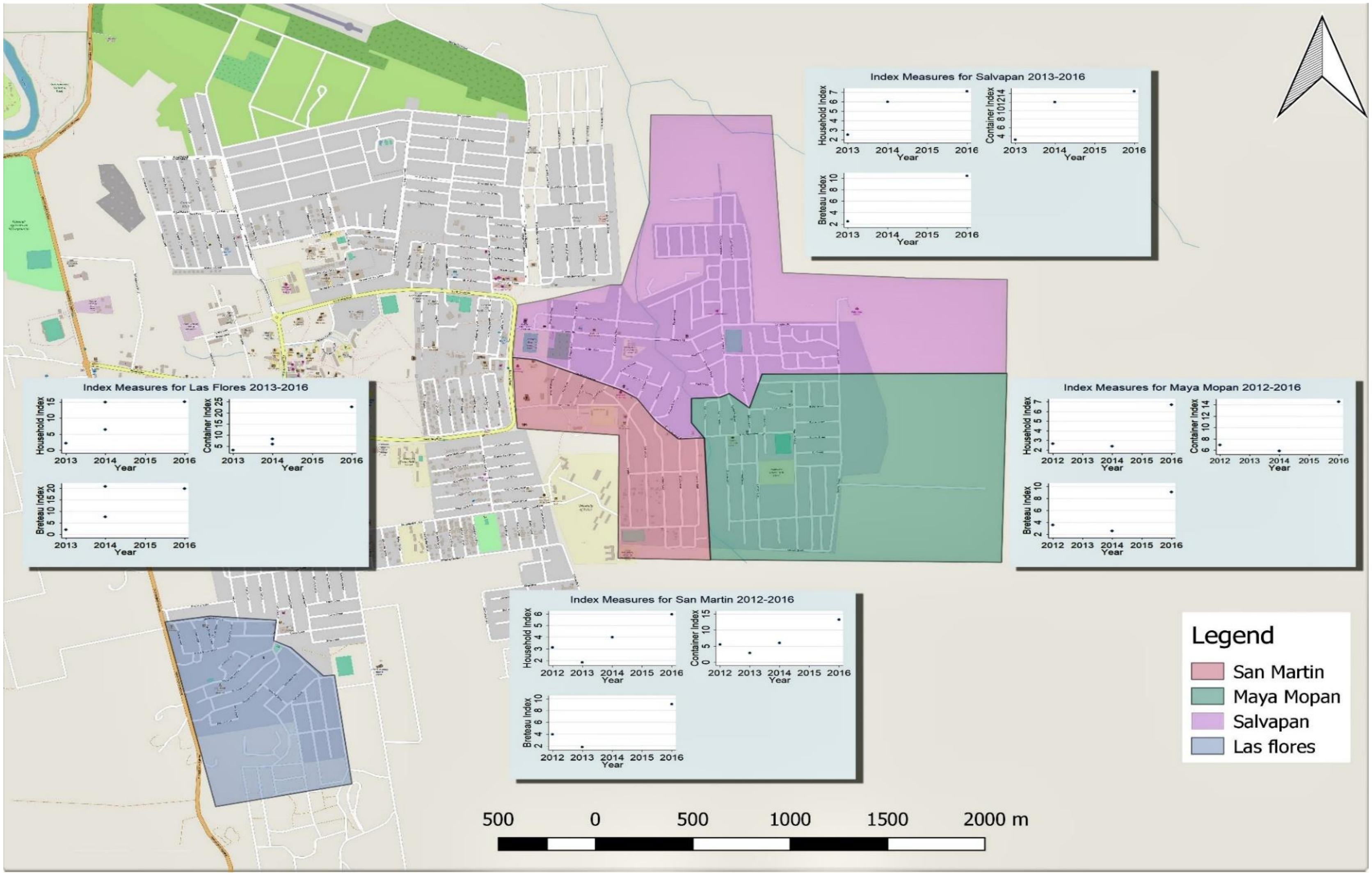


Figure 16: Measure of household, container, and Breteau indices for communities in Belmopan, Belize, 2012-201

3.2.2 Epidemiological Data

We calculated incidence and prevalence rates of dengue, chikungunya, and zika, from the data that was provided by the MOH. The following equations were used:

$$Prevalence = \frac{no. of\ cases}{population\ size}$$

$$Incidence\ rate\ or\ density = \frac{no.of\ disease\ onsets}{Sum\ of\ person-time\ @\ risk}$$

The population of Belmopan was said to be 17,307 persons according to the Ministry of Health. We were not able to divide incidence by community due to the lack of population data for these areas. Cases were defined as having a positive IgM or NS1 test reading. There were no confirmed cases of chikungunya therefore incidence rates and prevalence were calculated using clinically suspected cases. All incidence rates are reported as number of cases per 10,000-person years. There was no significance between mosquito indices and positive cases.

The incidence rate for dengue from 2013 to 2016 was 34 cases per 10,000 people. Prevalence for the four-year period was 1.35% which means that approximately 1% of the Belmopan population had contracted dengue in the last 4 years. Figure 17 shows the change in incidence over time. In 2014 and 2016 incidence is lower than in 2013 and 2015. In 2015 there was an outbreak of dengue which explains the extreme increase in incidence. A national report on dengue, chikungunya, and zika in Belize was released by PAHO for 2016 (Belize, 2017). Their reported national incidence rate for dengue was 5.5. cases per 10,000 person years. When compared to the incidence rate of Belmopan for 2016 there was no statistical difference when using a Chi-squared test. The PAHO report states that there was only one confirmed case of dengue up to epi week 46. The data we received on Belmopan reported two confirmed cases of dengue in the area from epi week 9 and 11. This difference could signify some reporting errors either with the data we received or the data PAHO received.

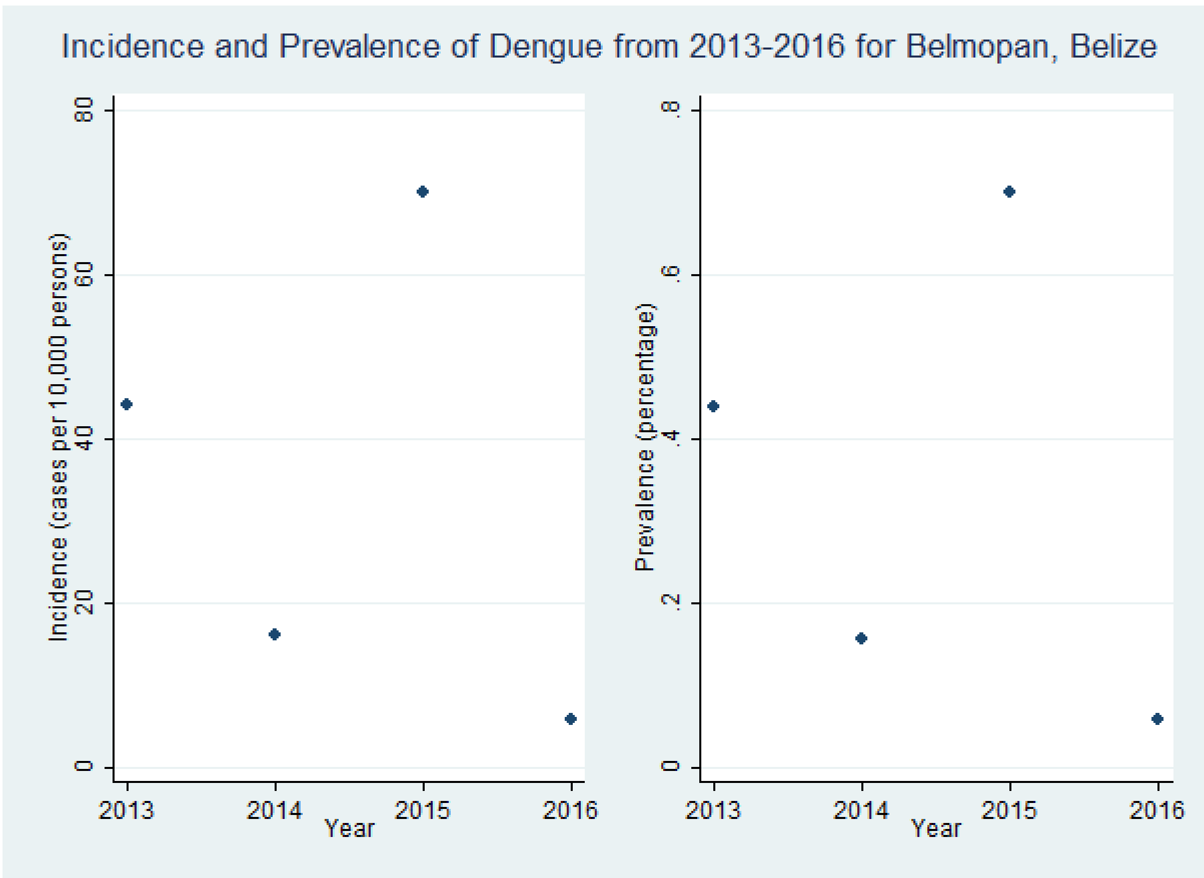


Figure 17: Incidence and Prevalence of dengue Over Time in Belmopan, Belize

There was much less available data for zika and chikungunya. zika was only introduced into Belize in 2016. The incidence rate was 3 cases per 10,000 persons with a prevalence of .029%. This is much lower than that of dengue in 2016. Chikungunya was introduced into Belize in 2015. The incidence of suspected cases was 5 per 10,000 persons in 2015, and 6 per 10,000 persons in 2016. Prevalence for these two years was 0.046% and 0.064%. We do see a slight increase in suspected cases between these two years. If suspected cases of chikungunya are treated as positive cases, when comparing this to dengue it is demonstrated they have similar incidence rates for 2016, although prevalence for chikungunya is higher than the 0.058% prevalence of dengue.

There was insufficient time to corroborate all the data received with the BHIS in order to ensure quality and that cases were in fact within our targeted population area. With the help of Western Regional Vector Control personnel, we were able to do this with the years 2015 and 2016 for dengue. We found that there were some inconsistencies in reports. Some suspected by clinical cases for dengue actually had a test conducted that came back negative, according to the BHIS. These cases should have then been reported as being suspected by test but were not. We also found that some suspected by test cases had a positive result but were not considered probable cases. There was also never a clear way of reporting a negative result as zero and missing could have meant negative or a not conducted test. These inconsistencies could present potential issues in drawing conclusions from the epidemiological data.

3.2.3 Review of National Strategic Plan and Education Materials

National Strategic Plan

During the stakeholder consultations, we were informed that our study should align with the goals and objectives of the National Dengue-Chikungunya Action Plan

2015-2020. The main purpose of this plan is to reduce the social and economic effects of the diseases. The primary objective is to have a 20% reduction in dengue and chikungunya incidence by 2020. This objective will be carried out by the Ministry of Health and align with PAHO/WHO strategies, and the Regional Master Plan for the Integrated Management of Dengue/Chikungunya Prevention and Control. We were not given access to these other two strategic documents.

There are six primary components covered by the plan; integrated strategies, epidemiological surveillance, lab diagnostics, patient care, and integrated management utilizing advocacy, partnership, communication, and collaboration. Our study primarily fits into the integrated strategy and management components and only slightly touches on epidemiological surveillance. The University of Notre Dame has been carrying out research in regards to the other components.

Figure 18 shows the overall goal of the integrated strategy component. Tasks to complete this goal include the development of an integrated management strategy that is agreed upon by stakeholders and integrated into regional efforts and a formation of a technical group. It is important to note, that through our own observations, we believe the assumptions for this component have not been met for the Western Region due to the extreme lack of human resources for the area. Therefore, the Western Region may not be able to achieve the indicators represented. It is unclear if any of the additional tasks have been achieved. Our study helps to analyze risks using many kinds of data, including entomological and epidemiological. Therefore, our study can perhaps help the Western Region achieve some goals in this component.

Component: Integrated Management Strategy for Dengue and Chik-V

Expected outcomes	Indicators	Sources of verification	Assumptions
Implementation of appropriate vector control interventions based on stratification of risks, guided by entomological and epidemiological indicators	1. 100% of district programs based on the framework of IVM 2. 100% of field officers trained in the core competencies of IVM	• Regional Health Plans • Annual Reports • Training/Activity reports	Adequate human resources installed at the various health regions to adequately address vector borne diseases of major importance

Figure 18: Integrated management goal from the National Dengue-Chikungunya Action Plan

Figure 19 shows the overall goal for the epidemiology component. Through our own observations this goal and its related tasks are mostly being carried out. For example, the Western Regional Vector Control Unit uses the BHIS to monitor and investigate cases and have assured us that they use epidemiological reports to better focus their efforts. Figure 20 is an example of one of the activities under this component. The second box in the shown figure is the task that should be conducted to achieve the given activity. However, this task does not seem very plausible. It is unclear what the task means by weekly analysis. Time-trend analysis is conducted by recording observations at equal time intervals and then combining that data to look at the overall trends (Bailey et. al., 2005). The way in which this task is written appears to be asking regional teams to collect data daily and analyze the time-trends weekly. As chikungunya and some of the other vector-borne diseases are rarer, it seems that weekly trends would not be very informative. A more plausible task would be to collect data weekly and then analyze the trends over a quarterly or yearly basis to inform the use of resources.

Epidemiology Component: Expected Outcomes—Indicators—Sources of Verification and Assumptions

Expected outcomes	Indicators	Sources of verification	Assumptions
Strengthened surveillance system for dengue and chikungunya prevention through early detection and containment of outbreaks	1- 100% of regional health teams having carried out internal sensitization of health care workers and implementing surveillance measures for Dengue and Chik-V 2- 100% of the countries issue periodic epidemiological bulletins that contain an integrated analysis of the situation of dengue and CHIK as of 2017. (Quarterly or annual National epidemiological bulletins developed)	• National epidemiological reports • Belize Health Information System Reports and Alert System in Use • Reports to PAHO/WHO • IMS-dengue progress reports	Compliance in the use of the National Health Information System

Figure 19: Epidemiology goal from the National Dengue-Chikungunya Action Plan

3- Exchange of information through surveillance team for action	Conduct weekly analysis of trends to stratify epidemiological situation to ensure best use of resources	X			Regional Health Management Teams	

Figure 20: Epidemiology activity, task, timeline, responsible party, and budget from the National Dengue-Chikungunya Action Plan

Figure 21 shows the integrated management component. Through the use of CBPR and bringing together stakeholders, our study best addresses this component of the plan. Tasks under this component include, creating strong networks with local stakeholders, developing and implanting behavioral and communication initiatives, and conducting activities with public and private sectors within the community. We were not given access to the COMBI strategy that is discussed in this component.

Advocacy, Communication, Partnerships and Collaboration component: expected outcomes—indicators—sources of verification and assumptions

Expected outcomes	Indicators	Sources of verification	Assumptions
Build multi-sectorial partnerships with key stakeholders to educate the public on vector borne disease prevention and control to enable collective decisions and actions aimed at reducing transmission	Regional Management Team with established partnerships with local government and relevant stakeholders. Communication for Behavioural Impact (COMBI) Strategy implemented within all districts targeting hotspots	• Combi plans • Surveillance Team Minutes and reports	Teams with necessary inputs to conduct activities in rural areas. Management teams ability to engage stakeholders throughout the process

Figure 21: Advocacy, communication, partnerships, and collaboration component goal from the National Dengue-Chikungunya Action Plan

Overall the national plan aims to improve many areas related to vector control and our study can perhaps find ways to align with the plan. However, it is difficult to align our study with the national plan due to the lack of specificity. For example, the tasks are very broad and there is very little guidance in establishing formative, process, outcome, or impact evaluation. Each component has an overall outcome, indicator, source of verification, and assumptions, but the individual activities lack such guidance and structure. It was also not reported to us if at this time any or all of the goals are being achieved. Perhaps the strategies that we did not have access to had more specific goals and outcomes that could better guide implementers.

Education Materials

As part of the project, we were granted access to new learning materials for mosquito and disease education. These materials were developed in partnership with the Ministry of Education, PAHO/WHO, and UKAID. The curriculum is called *SWAT* and it includes a workbook, a play, and a game. Materials are in both English and Spanish. These materials demonstrate the ongoing actions taken by the Ministries to begin targeting behavior change at younger ages, which coincides with previous recommendations made by respondents. Assessment of these materials provides a more holistic understanding of vector control efforts.

To truly assess the quality of materials it is important to know learning objectives, if any needs assessments occurred, the training teachers will receive, and if there is any plan for evaluation in place. This information was not made available to us, therefore, a basic review of the materials is all we can accurately provide.

The workbook has ten different missions for the students to complete (Figure 22). The student takes on a similar role to a health inspector and their number one enemy is the *A. aegypti* mosquito. Each mission has a specific problem and objective that is presented to the student in a variety of ways. The missions utilize team work, word searches, word scrambles, cross words, true/false questions, and independent learning as ways to teach and reinforce the information being learned. The information covers mosquito behavior and life cycles, breeding sites, preventative measures, how to educate the public, and facts about the diseases mosquitos carry.

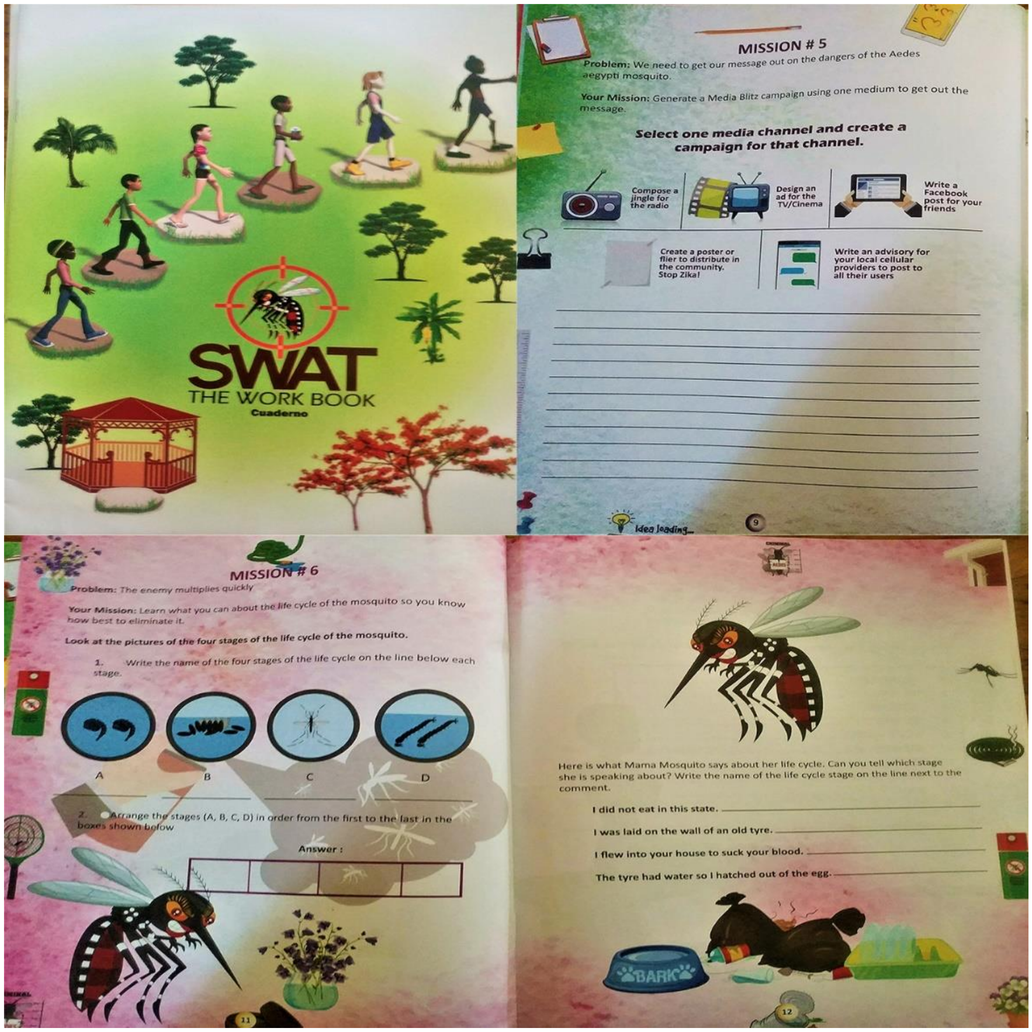


Figure 22: SWAT workbook cover and missions

A few missions are of particular interest. Mission 2 asks the student to list and name diseases first, then to ask a friend a few questions related to whether or not they or someone they know has ever contracted one of the diseases. This is an interesting way to have the students learn more about the diseases through personal experiences and demonstrating that the diseases are present in their community. This is especially true if the teacher has them complete the mission as a homework assignment and report on it the next day, so that the student can understand how the diseases effect the community.

Mission 5 and 6 have the students create a poster and a social media campaign to educate others. Not only does this help them creatively apply their knowledge but could be used to insight greater involvement in the issues. Mission 6 requires the students to make a check list of possible breeding sites. If the teacher emphasizes that the students actually carry out this check list at home as a homework assignment, then the teacher reinforces positive behaviors.

A possible way to utilize the workbooks further would be to use the posters or campaigns at the school by posting them in public areas to educate the other classes. All the posters of the class could go up or the teacher could make a friendly competition out of the assignment with the top three posters or campaigns being posted around the school. This recognition of the students' assignments creates a novelty for learning self-efficacy, assists in increased interest in goal obtainment, and can be a powerful motivator for some students to maximize their success (Renchler, 1992; Margolis and McCabe, 2006).

Overall, the workbook is accurate, somewhat informative, and provides many learning opportunities for the student. The workbook focuses on the learner and integrating material into real life situations and utilizes multiple methods for reinforcement which follows closely with the constructivist theory of learning (Tamim and Grant, 2017). There is also some integrated behavior development and reinforcement which is very important for the students to begin learning positive behaviors that can be practiced in the real world. It is unknown what information the students will receive from the teacher prior to completing each mission, as some missions seem to require additional information not included in the workbook. It is also unknown how the materials will be taught and implemented by the teachers. Therefore, further evaluation of the materials is difficult.

The *SWAT* play and game further establish and reinforce what the students learned from the workbook (Figure 23 and 24). The play follows six children on their quest to defeat Viralla Di Zease the *A. aegypti* female and villain. They all in live in a place called Rose Hill and must hunt Viralla through the town in order to finally take her down. Their adventure takes them to flower shops, mechanic shops, friends' homes, and other locations you may find in any city. At each location, the characters meet someone new and in the process, learn more about mosquitos and ways to prevent them. It is a very thorough yet short play and could be done by most elementary school students.

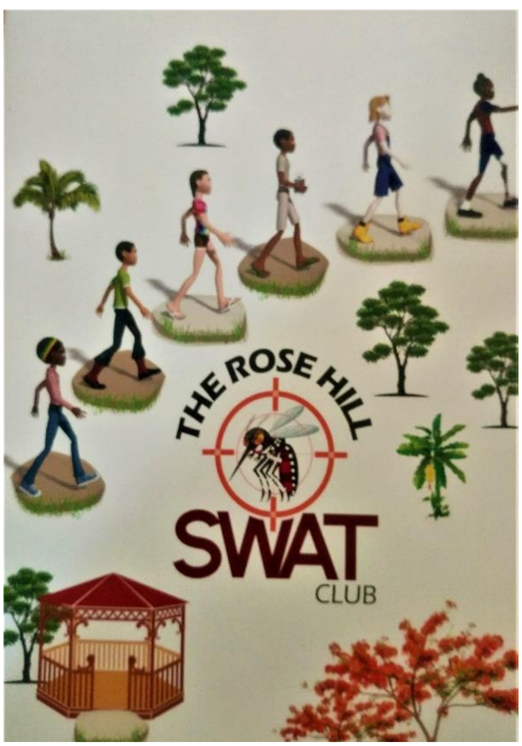


Figure 23: SWAT play booklet cover

The game was the most hands on of the three materials. Each player would pick a pawn to act as their representative on the board. They would then role a die to move their piece forward along the path. At every location a card would be drawn that would provide a scenario and require the player to answer a question about mosquitos, preventative practices, or breeding sites. Through these cards players would test their knowledge of proper behaviors and facts in regards to mosquito control. To win the game the player must answer all questions correctly and reach the gazebo to collect the golden token.

Figure 24: SWAT: The Board Game

We played the game multiple times with a four and eight-year-old, who are likely around the target age ranges for the curriculum. The children were able to understand the game and found it enjoyable to play. For the eight-year-old, the game was not too challenging, and, if he had been a year or so older the game may have become too easy for him. The four-year-old found the game a bit more challenging and needed more instruction to answer the questions, but, with help he was able to understand and move through the game with ease. It was most fascinating to find that weeks after playing the game the four-year-old would turn to me and identify mosquito breeding sites and accurately describe how to prevent them. This demonstrates that the game was an effective tool for behavior development; however, more research is needed.

4. Discussion

4.1 Data Summary

The primary purpose of this study was to utilize CBPR approaches and the PRECEDE-PROCEED model to guide the implementation of a comprehensive needs assessment that would provide targets for future health promotion programs, and strengthen the capacity of the community to participate in research and control efforts. This theoretical framework was key to the study design and implementation, and the organization of the findings. Results have been presented to fulfill the first four phases of the model by reporting on social, epidemiological, entomological, behavioral, and administrative needs in regards to vector control. The discussion provided is aimed to summarize the major targets found during the PRECEDE phases so that stakeholders may utilize the findings to inform the PROCEED phases for future program design and implementation at all levels.

Knowledge of diseases and mosquitos can still be improved among residents. Other studies evaluating knowledge, attitudes, and perceptions (KAP) evaluated high knowledge as having an 80% efficiency, which follows Bloom's cut-off points (Bloom *et.al.*, 1956; Shuaib et.al., 2010; Abedi *et.al.*, 2011; Dihmal *et.al.*, 2014). Only nine respondents demonstrated this level of efficiency of knowledge therefore, proficiency was extended to 60% and above. This low number of individuals achieving 80% efficiency may demonstrate that current educational efforts are lacking and need improvement.

The fact that only 11% of respondents were able to clearly identify rash as a recognizable symptom of dengue, chikungunya, and zika corresponds with the low levels of knowledge among the community. Due to the limitations of this study, this may be underreported as research assistants did not ask if respondents knew specific symptoms. However, this has been demonstrated in multiple KAP studies on dengue in other countries (Van Bentham *et.al.,* 2002; Acharya et.al., 2005; Shuaib et.al., 2010; Lopchan, 2012; Dihmal *et.al.,* 2014). If respondents are only able to recognize headache and fever as common symptoms then these diseases could be confused for the flu or other common illnesses, leading to possible delays in seeking medical treatment.

It is not uncommon to see a lack of association between knowledge and most sociodemographic characteristics, as demonstrated by other KAP studies (Hairi *et.al.,* 2003; Shuabi *et.al.,* 2010; Al-Dubai *et.al.,* 2013; Dihmal *et.al.,* 2014). The association of higher education with lower levels of knowledge could be due to a number of factors. The multiple logistic regression model demonstrates that those with more education are reporting that their schools provided them with information. The lower association could imply that there might be very little information provided by schools or that the information is of low quality. Further research needs to be done to determine this because the current study is unable to confirm these hypotheses. The *SWAT* curriculum could be the focus of such research.

The higher proficiency association with income could indicate that those with higher levels of income may have access to more sources of information such as TV, Radio, and online sources. The most significant sources contributing to knowledge are MOH and media sources. This coincides with research assistants' observations stating that the MOH is the major distributor of knowledge-based materials in regards to vector control.

Over 90% of respondents perceived mosquitos and associated diseases to be a threat either to themselves or to the community. This demonstrates that many people have a perceived risk and are relatively supportive of mosquito control. Those who do not have this perceived risk will be difficult to target for future health promotion programs and should be kept in mind when providing information to the community. It is also possible that the high levels of perceived risk are due to a cultural or social bias as found in other studies (Hairi et.al.,2003; Dihmal *et.al.,* 2014).

It was observed that the majority of respondents cleaned their yards and turned over or cleaned water storing containers to help prevent mosquitos from breeding. Other positive practices were high use of mosquito nets, mosquito coils, and fans. Unlike other KAP studies a score was not assigned to positive practices; however, the data demonstrates that people are practicing positive prevention measures despite having low knowledge, which has been observed in other studies (Van Benthem *et.al.,* 2002; Dihmal *et.al.,* 2014; Alobuia *et.al.,* 2015). This may be because of information spread by the MOH that focuses on preventive measures but may not provide thorough disease and mosquito related information.

Association between mosquito net use and disease possibly indicates that contracting a disease may assist in the decision to buy and use mosquito nets. The spatial analysis of mosquito nets is inconclusive. This is because of the lack of significance of the spatial model, and high standard error in areas with higher odds. An explanation for these issues may be contributed to the smaller density of data within areas predicted to have higher odds. Also, the sample sizes, within each community, are small which also affects the model's ability to predict the spatial relationship. Therefore, a greater or denser local sample size is needed to determine if the relationship is random or real. Perhaps the best focus would be to have a denser sample in Las Flores and Maya Mopan to determine if location is a predictor of mosquito net use. Future research could also see what the true correlation between mosquito net use and disease is within these denser samples.

The fact that people in Maya Mopan and Salvapan were more likely to use nets yet less likely to contract disease indicates the possibility that net use is effective in preventing further disease cases. People in Las Flores are the most likely to contract disease and least likely to use nets. This contradicts the previous inference that net usage is increased after a disease is contracted. Other factors may contribute to the relationship between net usage and disease, but this study could not determine this. Further long-term studies could be conducted that analyze the pathways of correlation between net usage and disease.

It is difficult to determine whether or not reported practices were translated into actual practice; however, some discrepancies were found through our observations. Although only two of those who reported having cleaned their yard regularly were observed to have unkempt yards, 48 respondents had some sort of recycling, that could have become a potential breeding site, despite reporting cleaning their yards regularly. This discrepancy demonstrates that there is a loss of validity in reported practices. It is also possible that people have differing ideas of what a clean, mosquito free yard looks like or that we observed the yards before they were to be cleaned. In either case it is important to continue to inform individuals of what a clean yard looks like that will not attract mosquito breeding.

The entomological data demonstrates that respondents in our survey are living in areas with high levels of infestation. However, conclusions based upon entomological data are limited. It has been found that mosquito indices may not predict the possibility of outbreak on their own, especially in areas that are endemic (Sanchez *et.al.,* 2010; Bowman *et.al.,* 2014; Chang *et.al.,* 2015). It also becomes more complicated to draw conclusions from entomological data when there is no agreed upon universal threshold for determining high infestation (Who, 2009; Bowman *et.al.,* 2014; Chang *et.al.,* 2015). I decided to use WHO recommended thresholds as these are the most widely accepted (Who, 2009).

Indices are found to be most predictive of outbreaks when combined with epidemiological and meteorological data (Bowman *et.al.,* 2014). Our study found no association between indices and positive cases. This is also limited because epidemiological data could not be analyzed by community due to insufficient cleaning and lack of population data for targeted communities. Meteorological data was not collected. However, this could be used in future studies.

Epidemiological data demonstrates that Belmopan is at risk for dengue, zika, and chikungunya. A lowering of incidence in 2016 for dengue after the outbreak is a desired outcome, which may infer that control efforts were effective. However, this could also be confounded by the possibility of less rainfall that year or other effects due to climate change. Analysis of climate variations on epidemiology would be beneficial for future surveillance efforts. The inconsistencies in national reports with data that was received as well as inconsistencies within the data set are barriers to swift surveillance. These issues lower the quality and validity of the epidemiology data and in turn lowers the ability of swift surveillance to occur if there is an outbreak. How the data is being collected and reported should be evaluated to determine why these inconsistencies have occurred.

4.2 Implications for Policy and Practice

Future vector control efforts need to be multifaceted by combining a variety of scientifically-based efforts in order to overcome barriers for change and more effectively control mosquito populations (Heintze *et.al*, 2007). Program interventions will need to employ theories of behavior change such as the Health Belief Model, Transtheoretical model, Social cognitive theory, and theory of planned behavior. These theories can be applied to program implementation to ensure that efforts are effectively targeting and influencing people to accept and adopt behavior change (Langlois and Hallam, 2010; McKenzie et.al., 2016). Future efforts also need to allow the community to take charge of their own health and allow the government and organizations to become a facilitator of these actions rather than the primary controller (Spiegel *et.al.*, 2005). Allowing the community to take ownership of future programs lessens the burdens of government officials, lessons the reliance on limited government resources, and can assist in sustainability of efforts (Spiegel *et.al.*,2005; Hacker, 2013). Actions also need to encourage stakeholder involvement and working with local entities like churches and schools to encourage adoption of efforts.

I have provided a few recommendations based upon the assessment and recommendations of respondents that may be most beneficial and rooted in the theories for future health efforts. Many of the recommendations take into account barriers that may prevent adoption of behavior change. Barriers that Belmopan residents experience include a lack of money to buy prevention materials; a lack of time to practice prevention measures; a lack of knowledge; inaccessibility of information due to language; lack of access to markets that sell materials; and misconceptions about the problem. Stakeholders also experience barriers such as lack of resources both monetary and human; a lack of knowledge about where improvements need to be made; a lack of evaluation in regards to interventions; and a lack of networking among relevant organizations. These lists of barriers are not exhaustive however future interventions need to overcome these and other barriers in order to achieve behavior change in the community. All recommendations for future interventions, if implemented, will need to have a strong evaluation plan to ensure their efficacy and quality. Identifying areas for improvement and providing recommendations for decision makers is one of the primary goals of the project; therefore, the majority of the discussion is embedded within the recommendations.

Education and Knowledge Targets

Education has proven effective in reducing mosquito populations in other countries and adequate knowledge is linked to positive practices (Espinoza-Gomes *et. al.*, 2002; Koenraadt *et.al.*, 2006). As a predisposing factor that encourages motivation and behavior change, knowledge needs to be increased among the Belmopan community (Langlois and Hallam, 2010). According to the transtheoretical model, in order to act, people need to have weighed the benefits and barriers to behavior change and have confirmed that the benefits outweigh the barriers (Prochaska and Velicer *et.al.*, 1997). The following education targets, therefore, focus on encouraging people to contemplate, and prepare for the behavior change. Yet this can only be done if the information is accessible. These education targets are meant to increase the accessibility of information and how people respond to the information provided. Much of the feedback received supported this, as well. Many of these education targets will not require an abundant amount of resources and should be easily employed when stakeholders work together. Behavior change takes time. Therefore, solutions need to be employed consistently over the course of many months or years to produce the desired effects. Use of proper program implementation techniques can facilitate this implementation.

- Accessibility: using scientifically based messages

    - Increase social media presence
    - Provide scientifically based education materials in Mayan languages
    - Make sure education materials have more diagrams and visuals
    - Provide information in the form of pamphlets or posters about where to acquire inexpensive products that will help protect against mosquitos.
    - Post pamphlets/posters in public areas such as markets, parks, or tortillerias
    - Increase verbal communication of information through community meetings, home visits, radio, or TV
- Content
    - Focus information on distinct symptoms of the diseases
    - Focus on chikungunya related information
    - Increase *Anopheles* control information
    - Deliver information in a way that focuses on perceived threats, perceived severity, perceived susceptibility, perceived benefits, and interpersonal effects
    - Effectively implement, evaluate, and utilize school curriculum on mosquito control

Accessibility targets were mostly provided by the recommendations of the respondents. Spanish was not included as a provided language because the Ministry of Health is already providing information in this language. Additional pamphlets should be created about where to acquire materials so that people are able to assess which measures they can afford and actually know where to buy them. This will help them better contemplate and prepare for behavior change. It would not be difficult to visit different stores within the communities and gather information on the products they provide; however, it would take time and personnel.

It is also important to understand how information is being spread through the community. A few respondents mentioned that neighbors, friends, and family members would provide more information and share personal experiences on mosquitos and the diseases they carry. Utilizing these social networks can help the Ministry and other organizations spread information faster and farther throughout the community (Hodas and Lerman, 2014). Social networking may also help the information reach people who are on the outskirts of the city limits or in the underdeveloped and bush areas.

Content targets focus on what was represented in the data collected from the surveys. By focusing education on distinguishable symptoms, health inspectors can help ensure patients seek treatment in a timely manner. The greatest gaps in knowledge were in regards to chikungunya, zika, and mosquitos. This was especially true for those with a higher education. chikungunya and zika have recently been introduced in the community, therefore, the knowledge of these diseases is expected to be lower. The reason chikungunya is emphasized is because zika may no longer be a threat after the initial outbreak (Groopman, 2017). Although zika should not be forgotten, it may be more beneficial to increase efforts on chikungunya information and leave zika information delivery the same.

Respondents demonstrate a higher level of knowledge for malaria than some of the other diseases, therefore, an increase of information about the disease is not necessary. However, the number of malaria cases found among respondents may demonstrate a reintroduction of the disease into the community. Consequently, there should also be an increase in information on how to control the *Anopheles* mosquito. This demonstrates a need for vector control to not reduce efforts once a disease has supposedly been eradicated. Their efforts and policies need to adapt to mosquito behavior as well as transition from promotion to constant prevention.

Information needs to target people who do not perceive mosquitos and the diseases they carry as a threat. These people are less likely to take action and may not take preventative measures. Emphasizing how the diseases effect daily life, productivity, finances, and children can convince these individuals of the importance of learning about and preventing these diseases, especially since other respondents mentioned these as reasons why the diseases were a perceived threat to them. Also, focusing on the interpersonal nature of the diseases and disease spread can encourage people to see the benefit not only to themselves, but also to the community when they take preventative measures (Langlois and Hallam, 2010). This will be a significant barrier to overcome when encouraging behavior change.

Educational targets would be enhanced by employing the diffusion of innovation theory in order to increase the spread and marketability of information. The theory can be employed to increase attendance of health promotion programs, which was only reported favorable by 67.71%. The theory describes how information and interventions are distributed to the members of the community through different communication channels (Rogers, 2003). It also describes the type of people who will adopt the program such as the innovators (2-3% of priority population), the early adopters (14% of priority population), early majority and late majority (34% of priority population), and the laggards (16% of the priority population) (McKenzie *et.al.*, 2016). The innovators and early adopters should be targeted at the onset of any future efforts as they will then spread and increase participation to the early and late majority. Laggards will be the most difficult to target and these would include those who do not perceive mosquitos and diseases to be a problem. It is important to keep this theory in mind when planning how to disseminate interventions and information into the community.

Vector control efforts in Belmopan are also expanding into other areas such as primary education. The effects of the educational materials are not established yet as the materials will be implemented within the next year. However, there is some evidence that the curriculum will be successful due to the effects the game play had on the children weeks after playing. Firstly, these materials need to be integrated into the schools in a way that utilizes behavioral research findings. These materials would be more beneficial, in contributing to behavior change, if adapted for the communities for which the curriculum was being implemented. For example, in Belmopan emphasizing to the children what a truly clean, mosquito-free yard is, ways they can pick up trash not only around their home but in the community, and ways to get rid of stagnant water during the rainy season would be most applicable for these children. Secondly, to ensure the curriculum is effective proper evaluation needs to be in place. Not only does this evaluation ensure the curriculum is properly implemented and effective but can also be utilized by the stakeholders for future research. Stakeholders can determine at a later time if increase in knowledge occurs within the community due to the implementation of this curriculum.

Finally, the curriculum can also be utilized by the stakeholder group to spread knowledge and community awareness beyond the school environment. For example, the City Council could encourage a school, within Belmopan, to put on the play as a citywide event. This would encourage parents, family friends, teachers, and perhaps a few non-related community members to attend. Not only are the students gaining knowledge about mosquitos but the attendees will also be learning. This provides an opportunity to utilize the diffusion of innovation theory as well. Another option is to utilize the ideas and designs students have for campaigns and implement those on social media or around communities. This provides recognition to students and could increase the flow of activity to MOH run platforms and media, thereby encouraging the spread of knowledge to parents and to people within their personal social networks. The curriculum provides an opportunity to work across stakeholder groups, expand efforts, and increase community knowledge and participation.

Behavioral Targets

Behavioral targets are meant to guide future vector control efforts to target practices that were lacking or health inhibiting within the communities. These targets encourage actions to be taken by the community and increase their preparation to take action.

- Emphasize using health enhancing behaviors for mosquito control that may be alternatives to health inhibiting behaviors
    - Screening windows/doors
    - Yellow bug lights
    - Citronella/other repelling scented candles
    - Mosquito traps
    - Planting plants that naturally repel mosquitos
    - Biological measures like using fish in water storage containers
    - Cooking sprays or cooking oils instead of burn oils
- Increase community clean up campaigns
    - Properly market these campaigns to the community in advance to encourage participation
- Provide materials to encourage behavior change
    - Mosquito nets
    - Screening materials
    - Covers for water storage containers

The data demonstrated that a mix of health enhancing, and health inhibiting practices were being utilized by households. Health enhancing practices, like the use of Fish coils, presented health inhibiting problems despite being an effective measure against mosquitos. Also, some health enhancing behaviors were under represented in the community and needed to be further encouraged. Therefore, the generated list of practices for this target are identified as practices that will encourage use of alternatives to health inhibiting behaviors. The Western Regional Vector Control Unit should continue encouraging practices they are already targeting such as clean yards and cleaning containers.

Screening windows and doors should be a primary method of mosquito prevention, yet, according to respondents, the cost of this measure prevents implementation. This was reported by respondents despite having no statistical significance between income and reported screening behaviors. This lack of significance could be explained by underreporting of income as many respondents skipped this question, or underreporting of screening windows and doors as respondents may not have seen this as an active measure against mosquitos. Belmopan residents should still be encouraged to conduct this practice and be provided with cheap ways to screen their windows and doors. Yet this will likely be the most difficult practice for them to adopt.

Yellow bug lights and scented candles are adequate alternatives to Fish coils but are not equivalent in their repelling effects (Dhang *et.al.,* 2007; Faiman *et.al.,* 2014). Very few respondents employ these methods. Yellow bug lights are helpful in repelling nocturnal insects, not just mosquitos, and therefore can be helpful in deterring *Anopheles* nocturnal species (Shimoda and Honda, 2013). However, this practice is not as effective in deterring *Aedes* species as they are dawn and dusk feeders. Scented candles can be beneficial in providing limited protection against mosquitos. However scented candles should not be presented as an equivalent to mosquito coils because protection provided by candles is restricted by space and how long it is burned. Citronella, eucalyptus, and lavender are scents that have mosquito repelling properties (Seyoum *et.al*., 2002). Candles can be an expensive measure. A cheaper alternative practice would be to use bug sprays.

Mosquito traps are an effective way of preventing mosquito bites and targeting adult mosquito populations but are not being utilized in Belmopan, according to our data (Okumu et.al., 2010). Many cheap and effective ways to create homemade traps are available online. The traps mimic scents and chemicals that humans release that attract mosquitos. The mosquitos then become trapped and die of dehydration in these contraptions (Patel *et.al.*, 2012). Traps are useful in killing other insects like sandflies. Pamphlets can be provided to residents about how to make these traps and the educational curriculum in primary schools could teach children to make the traps. This method is not being utilized by the Belmopan community.

There are many plants that can be used to repel mosquitos through their natural aroma, spraying their oils, or by burning them. Some of these plants and trees are common to Belize such as basil, eucalyptus, lemon grass, citronella, cedar, neem trees, wild sage, *Hyptis suaveolens Poit* or pignut, and others (Arvigo and Balick, 1993; Westdyk, 2010;

Balick and Arvigo, 2015). Many of these plants have been utilized in traditional medicine practices in Belize, as well (Arvigo and Balick, 1993; Balick and Arvigo, 2015). The most effective way to use these plants is to burn their dried plant material. Planting them or using their oils can also repel mosquitos (Seyoum et.al., 2002; Maia and Moore, 2011; Schubert, 2014; Pavela and Benelli, 2016). These plants could be planted around shade trees, latrines, and other areas found to be problematic by the community which would help to prevent mosquitos from resting in these areas. Also, the burning of these plants would be more beneficial and less hazardous than burning garbage as there would be less toxic chemicals released.

Using other biological measures can be expensive; however, they are effective in preventing mosquito breeding and are safer than using larvicides or chemicals. Bti is a bacterial larvicide that is effective against resistant populations and can be applied in similar ways as chemically based larvicides (Setha *et.al.,* 2016). Effective biological measures have been the use of fish and crustaceans to reduce larvae (Lardeux *et.al.,* 2002; Nam et.al., 2005). The introduction of dragonfly larvae or *Toxorhynchites* may also be effective as these are known mosquito killers and harmless in regards to disease spread (Miyagi et.al., 1992).

Finally, placing burn oil or Clorox in puddles can be harmful to humans and the environment. There was a higher number of respondents who conducted this practice than what was expected. There was no association between this practice and other variables. Therefore, it is unknown what may lead people to begin using this practice. A safe alternative to burn oils are cooking sprays or cooking oils. The cooking oils are still effective in creating a thick film over the water's surface that kills larvae without the related impact on the environment and health of the community (Services, n.d). Using burn oils needs to be discouraged by the health inspectors.

Many residents wanted to see an increase in community involvement and this coincided with wants from stakeholders for the community to take charge of their own problems. One way to do this is to have community clean up campaigns at regular intervals during the year. This allows the community to take charge of their own health and hygiene and helps to tackle multiple problems. It can also be an outlet to bring awareness into the community. The Ministry of Health did have concerns as their previous efforts were not very successful. If the campaigns are marketed successfully in advance, by using Social Marketing techniques, and have community leadership then these will be more successful campaigns (Spiegel *et.al.*, 2005).

Preparation is the step before people can take effective action in changing behaviors. It is important that people have access to materials and understand that these materials are not difficult to come by. Therefore, it is advised that some materials need to be made accessible to people who may not be able to afford them. If residents must seek out materials on their own they may be more reluctant to begin practicing the behavior and refuse to conduct the practice (Prochaska and Velicer, 1997). This may explain why respondents are still not covering their water storage containers despite instructions provided by health inspectors.

The difficulty of employing this recommendation is the lack of resources of the government. There are possible ways to employ this recommendation resourcefully. One, if community meetings or campaigns are held to provide information an additional segment to the meeting would be to employ practices such as using mosquito nets, screening doors and windows, and covering containers. Some instruction could be provided on how to conduct these practices effectively and cheaply. Then at the end of the meeting each attendee could be provided with materials to take home and use for their household. Secondly, materials could be provided only to residents who have been targeted for premises inspections due to being diagnosed with one of the diseases. Finally, materials could be sold at a cheaper price to residents who have received a premises inspection after proper instructions have been given. These are only suggestions and should be further discussed by the stakeholders to determine the feasibility of the recommendations.

Environmental Targets

Environmental specific recommendations are grounded in Social Cognitive Theory utilizing observational learning, environmental factors, and ecological factors that encourage behavior change (Langlois and Hallam, 2010; McKenzie *et.al.,* 2016). Many of these recommendations should reinforce actions taken by the community to protect themselves. Perhaps if the members of the community are shown that the City is taking action and conducting proper measures to ensure mosquito control then community members will begin to see the importance of such measures. Overall these recommendations will be more difficult to apply to the community because of a lack of government and stakeholder resources. Therefore, the provided solutions attempt to be more manageable and are grounded in recommendations made by the respondents.

- Community organization and mobilization: Establish a Community Vector Control Committee
    - Installation of "No Dumping" signs near and around creeks
    - Installation of public trash cans throughout communities
    - Increase garbage pickup for communities
    - Regular cleaning/maintenance of drains
    - Installation of proper drainage where it is lacking in certain neighborhoods
    - Regular cleaning and maintenance of public areas
    - Solutions for empty lot maintenance

The primary solution to environmental risk factors is to encourage community ownership by establishing a Community Vector Control Committee or task force. Other studies have found that coordination between stakeholder groups and community members can help encourage adoption of practices and community ownership of control and preventative measures (Heitnze *et.al.*, 2007). Other studies have also found that community adapted interventions combined with continued government involvement is highly effective in controlling mosquitos (Andersson *et.al.*, 2015). To implement such a task force, the community action model should be used. This model is a five-step process that allows community members and stakeholders to address social and environmental determinants of health (Hennessey, 2005). The implementation of this task force would benefit the community by strengthening their capacities to improve health disparities and would be beneficial to government stakeholders as there would be less reliance upon their sparse resources. Through the use of CBPR methods and the PRECEDE-PROCEED model, this project has already begun building a foundation upon which this task force can be built. At stakeholder consultations, discussion of a task force was already occurring and the results of this study can be the foundation for the task force to design their interventions for vector control. The other environmental targets are more specific solutions that the task force could utilize for their future efforts.

The following three recommendations target trash problems found within the community. Trash can create artificial containers for mosquito breeding and can clog drains that then hold stagnant water for potential mosquito breeding (Paploski *et. al.*, 2016). As previously mentioned clean up campaigns can assist with the physical trash issues, but more can be done year-round to increase city-wide hygiene. Installation of signs was recommended by one of the participants and can bring awareness to the community to think about where trash is being placed. This, however, may not deter people from dumping their trash in creeks and drains. Therefore, installation of trash cans can provide designated and easily accessible areas to distribute one's trash, especially if they have a long walk to their destination. Trash cans will likely need to be metal, locked, and have proper covering in order to prevent tampering from dogs and being affected by rain.

For public trash disposal to be effective, garbage pickup frequency must be increased. This addresses the health inhibiting behavior of burning garbage to prevent mosquitos. It has been established that burning garbage is an effective, cheap, and quick way of ridding a household of their garbage especially in areas that are not serviced by garbage collection (Hilburn, 2015). Therefore, garbage collection routes need to be expanded throughout the communities and conducted on a more frequent basis. This may not fully prevent the problem as garbage burning could be grounded in the cultural practices of the people. Further instruction can be given to people about how burning garbage is hazardous and what are alternatives to prevent mosquitos in order to assist garbage collection efforts.

Drain cleaning, maintenance, and installation can prevent stagnant water build up both in the drains and in people's yards due to flooding. Although this is not normally a problem for *Aedes* breeding, it has been found that *Aedes* mosquitos can adapt to breed in dirty drains, and sewage water (Trpis *et.al.*, 1981; Paploski *et.al.*, 2016). Drains are also a breeding site for *Anopheles* mosquitos because stagnant water can build up in drains which then will contain algae and other leaf litter. In turn this creates a nutritious environment for the mosquitos to breed (Tariq, 2001). Expansion into bush areas and areas without proper drainage may also cause an increase in person to mosquito contact, especially with *Anopheles* mosquitos (Campbell-Lendrum *et. al.*, 2015). This may explain why there are more cases of malaria in the community than previously expected. Therefore, it is very important to maintain proper drainage.

The maintenance of public areas directly correlates with the desires of the City Council to make the city a more family friendly place. Respondents' identification of these areas as a problem demonstrate that the City Council may not be achieving their goals and should aim to maintain these areas more vigilantly. The task force can further discuss viable solutions to this problem.

Finally, there were many complaints and recommendations about empty lot maintenance. This is important to address as these areas are not only potential mosquito breeding sites but also hazards for other wildlife to take root. There is no easy solution for how to target this problem as empty lot owners may be unknown or unavailable for contact. It also requires strong enforcement of laws which is somewhat lacking among stakeholder groups. Therefore, stakeholders and community members should brainstorm further what possible solutions they can take to target these areas. No matter what solution is decided upon there should be a continued emphasis on community ownership and mobilization in order to address the issue.

Spraying and Fogging Targets

Spraying and fogging efforts are strongly controlled by the funding and resources available to the Western Regional Vector Control Unit and the City Council. Recommendations given by the people show a desire for increased efforts in these areas but it is not realistic with the amount of funding and resources available. If funding were to increase, then fogging and insecticide spraying could be conducted more often and throughout the year. However, this may run the risk of creating resistant mosquito populations. The following recommendations are believed to be most achievable by the stakeholders:

- Have community wide announcements prior to fogging that inform people when and how to prepare
- Fog off the main roads
- Fog around bushy and overgrown areas.
- Target drains and swamps with insecticides and larvicide
- Rotate the use of insecticides and larvicides

Respondents demonstrated that many households do not open their doors and windows when fogging occurs and that some people may be walking the streets at this time. It is important then that the City announce when they will be conducting their efforts in the community so people can properly prepare and open their windows and doors at the time. These announcements should instruct residents why it is beneficial to open doors and windows and also inform people to not walk near the truck as the chemicals could cause irritation. Instruction on how to protect household members, who have chronic diseases, from the insecticides should also be provided. It is also important for the fogging truck to target areas off the main streets and areas with bushier, overgrown spots. This will utilize the insecticides targets of outdoor areas rather than inside homes.

There is also a need for health inspectors to target dirty and water holding drains and swamps. Again, this may not be a very prominent issue, but *Anopheles* are likely to breed in these areas (Singh and Rahman, 2001). If the stakeholders want to prevent the *Anopheles* mosquito from reemerging as a public health risk, then it is important to target these areas. This could explain the number of malaria cases reported by respondents. Targeting drains also prevents *Aedes* mosquitos from possibly adapting to breed in these areas if other breeding sites are no longer available to them (Paploski *et.al.,* 2016).

The MOH is collaborating on a research project with Mexico to determine insecticide resistance in the mosquito populations found in Belize. Research shows that many of the insecticides used by the MOH are found to be creating highly resistant populations in other countries (Wirth and Georghiou, 1999; Rodríguez *et.al.,* 2002; Braga *et.al.,* 2005; Silva and Mendes, 2007; Alvarez *et.al.,* 2013; Bellinato *et.al.*, 2016; Ngoagouni *et.al.*, 2016; Goindin *et.al.*, 2017; Vazquez-Prokopec *et.al.,* 2017). What most researchers recommend is to find a period of rotation for the use of chemicals so that selective pressures are low (Bellinato et. al., 2016; Alvarez *et.al.,* 2013; Goindin *et.al.*, 2017). Researchers also recommend that larvicide and insecticide use should be integrated into other control programs but not be the primary source of control (Samuel *et.al.,* 2017). Samuel *et.al.,* 2017 recommends using an early warning surveillance system to control the application of insecticides is best practice for getting the most use out of the resources. This is especially true as most insecticides are only effective when there is high coverage of an area (Samuel *et.al.*, 2017). Rotating chemical use and limited use of insecticides may slow resistance to any one chemical (Goindin *et.al*., 2017; Samuel *et.al.*, 2017).

It is less likely that Belize vector control units will halt their insecticide and larvicide efforts, therefore it is recommended to rotate the use of chemicals periodically. The joint study with Mexico is likely to find populations with high resistance to Temephos and Delatamethrin as these have been used together for long periods of time. It is best to no longer use these chemicals. Malathion, Methoprene, and Spinosad are likely to have lower resistance in Belizean mosquito populations and should be utilized. Other chemicals should be considered for rotation so that selective pressure is lower.

Administrative and Policy Targets

Organizational targets are recommendations based upon the administrative and policy assessment. These recommendations hope to emphasize how the stakeholders can work within their own organizations and with others to best utilize their resources. These recommendations will hopefully help organizational actions that reinforce the proper behaviors within the community and among stakeholders to fight off vectors and related diseases.

MOH

- Train all health officers in program planning and evaluation
- Recruit UB students to assist in evaluation of interventions.
- Plan interventions utilizing scientific research findings and creating SMART objectives to ensure that objectives are achievable and measurable.

- Audit reporting of epidemiological data to ensure quality.
- Apply for international grants and funding for vector control.
- Western Regional Vector Control Unit
- Hire/recruit UB students to assist in premises inspections, information dissemination, evaluation of efforts, and secretarial work.
- Have a common database for input of data so that it is consistent and systematic.
- Use a password protected server to back up data files to ensure data is not lost.
- Correlate entomological data with other sources of information to increase surveillance.

City Council

- Provide greater assistance to the Western Regional Vector Control Unit by assisting in information dissemination and organizing community events.
- Increase their focus on people living at the edges of the communities.
- Partner with local schools and churches to put on community wide events.

UB

- Conduct research that coincides with vector control efforts and Ministry needs.
- Help with vector control efforts by providing human resources and helping to organize events.
- Ensure that the campus grounds are an example to the rest of the community by attempting to achieve a mosquito free campus.

Although recommendations are split by organization, all organizations should create a common coalition or task force that meets regularly to ensure that vector control efforts are optimally planned and implemented within the community. The task force should also involve community members. This can help ensure that resources are being used properly and that efforts do not become redundant due to multiple organizations focusing on the same interventions. In order to make sure that this works, a leader must be chosen among the stakeholders to take charge of the task force and all stakeholders must understand their role at the beginning (McKenzie *et. al.,* 2016).

The MOH is proficiently addressing vector control throughout the nation, but improvements could be made. MOH has difficulty properly evaluating their interventions. Although evaluation seems to be only a moderate priority for the MOH, it is very important in understanding the effectiveness of interventions and efforts. Therefore, an increased emphasis should be given to evaluation when implementing interventions. To increase the capacity of the MOH to evaluate, health officials should be trained in program planning and evaluation. This training should provide the appropriate knowledge for health officials to incorporate evaluation efficiently and effectively into their interventions.

A lack of human resources to carry out evaluation plans is also apparent. To address this barrier, the MOH can hire student researchers. The University of Belize students are usually searching for research opportunities or at least opportunities to better their resumes. Therefore, this is an abundant source of human resources and they do not necessarily need monetary compensation for their work.

Secondly, interventions should be based on research findings from this study or studies like it. Any future intervention plan needs to be informed by current research and incorporate a proper evaluation plan. Evaluation can help determine the effectiveness of an intervention and how to improve the quality (McKenzie *et.al.,* 2016). As such, project evaluation needs to be integrated during planning and implementation so that there can be adequate preparation for evaluation. This can be done by employing theoretical models, such as the PRECEDE-PROCEED model. These models provide a framework for planners to build upon and ensure proper implementation and evaluation. The current project is also an example of how these models can provide current research findings that will better inform implementation.

Assessment of the national strategic plan also demonstrates a need for planners to have more realistic goals and objectives. Objectives should be clear and define who is going to do what, when, and to what extent as well as be realistic (McKenzie *et.al.,* 2016). This technique for writing objectives could be used for all health promotion planning including future national, regional, and local plans. This would ensure that actions are being conducted properly, on time, and can easily determine why outcomes are being achieved or not. It also helps guide efforts and provides a clear idea of what implementation is meant to achieve.

An example of where proper evaluation techniques would be beneficial is for the mosquito net intervention that the MOH had conducted. The majority of people bought their nets from a store and even fewer received the nets due to someone being pregnant.

It would appear that the intervention did not significantly contribute to pregnant women using nets as only two respondents actually received nets from the MOH for this reason. However, distinct conclusions cannot be based on this data because it is not known how the nets were given out, for how long they were given out to pregnant women, and how many did they want to see given out to determine the intervention successfulness. There is no information on how many total women were pregnant during the intervention time frame in order to compare. A very simple and manageable evaluation would be to compare the number of nets given out to pregnant women versus the number of women who came to the hospital because they were pregnant. This would help determine if nets were being distributed properly. Even if this evaluation of nets never occurred at least there would be data available to analyze when resources and time were available.

The final two recommendations for the MOH are to improve the quality of their data and to help increase their funding. During the analysis of epidemiological data, there were many limitations in reporting. When cleaning data some patients were found to not be living in the Belmopan areas at all, according to the BHIS. A few cases that were suspected by clinical measures had actually conducted tests that came back negative. It is important for the MOH to train its research team in data collection and audit their data periodically to ensure its overall quality. However, the capacity for evaluation of epidemiological data is unknown. It would be beneficial for the vector control unit to seek out funding from international sources to assist in their efforts. These can be small grants provided by NGOs or other organizations and could greatly contribute to the resources that are lacking for vector control.

The Western Regional Vector Control Unit should also hire or recruit UB students to assist in their efforts. Minimal training would be required, and they could work part time or volunteer throughout the year. They could also work with the internship course, offered by UB, by providing multiple positions for students enrolled for the summer. This would assist in providing more human resources for their efforts.

Entomological data was difficult to analyze due to incomplete, lost, or nonsystematic collection of data. Using a common database that has a set structure would organize the data more efficiently for both entry and analysis purposes. This data base could be accessed by all personnel, including managers, in order to track progress and quality of data entry. Having this data base backed up on a common server would result in less data lost to viruses or misplaced ledgers.

The entomological data was able to show patterns of an overall increase in infestation since the year 2014. However, upon further research, entomological data is not accurate in predicting high risk areas alone. Instead, it should be combined with meteorological sources, and other environmental data to accurately predict possible at-risk areas. To properly use this data as part of the surveillance system, it should be combined with other factors that contribute to mosquito behaviors. A technical assistant from international partners could help to improve entomological surveillance.

The City Council needs to better support the efforts of the MOH and Western Regional Vector Control Unit for the Belmopan area. The Ministry of Health and Western Regional Vector Control are the most involved in providing information to the community through various means, and are able to expand their efforts by working with hospitals, TV broadcasters, and Radio broadcasters. However, due to limited resources, it has still proven difficult for the Ministry to meet the informational needs of the community. The City Council could best employ their efforts by assisting in information dissemination.

People living on the outskirts of the community, near creeks or off the main roads have the greatest problems in receiving services. These communities were observed to have poorer city hygiene, lacked proper drainage, received less fogging and spraying services, and were not as often visited by health inspectors. Expanding City Council efforts to these areas is important as they may lack the means to protect themselves against mosquitos and also are more at risk of contracting the diseases.

The City Council is also the most influential at the city and community level. By using their partnerships with local schools and churches they can help facilitate greater community participation. One possibility would be to encourage one or multiple schools to put on the *SWAT* play for the city. This would be a good way to utilize educational efforts to help spread information to children and their parents through social network connections. Also, it ensures community participation as parents are more likely to attend functions in which their children participate.

The University of Belize can provide support to efforts within the community by conducting research, leading projects that address vector control, and providing human resources to the other organizations. It is also important that UB act as an example for the rest of the community by practicing proper preventative measures especially since some community members voiced that UB property was a problem for mosquito breeding.

4.3 Areas for Future Research

This comprehensive needs assessment covers a wide range of information, but it lacks a more in depth understanding of some of the identified issues within the community and its stakeholders. Therefore, there are many areas where future research could be beneficial. For any future vector control efforts evaluation research should be conducted to determine the effectiveness of the interventions employed. Further studies could be conducted on the effectiveness of certain practices, like repellant plant use or yellow bug light use. More studies on mosquito behaviors especially in regards to mosquito resting and mosquito flight ranges, could assist in better understanding the effects of empty lots on mosquito populations. For surveillance purposes, research should be conducted that combines epidemiological, meteorological, and entomological data as this was lacking in our own study (Bowman *et.al.,* 2014). Finally, further CBPR projects could be established both in Belmopan and other villages to determine how the application of this research may differ among different communities. Overall there are many areas for future research in Belize that can build on the findings of this study.

4.4 Strengths and Limitations

This study is one of the first to be conducted in Belmopan and perhaps Belize, that attempts to conglomerate multiple sources of information and perspectives about vector control. It attempts to understand government, health, and community perceptions on mosquitos and problems associated with them. The study also allows the community to participate fully in the research process to ensure increased credibility and confirmability of the results (Lincoln and Guba, 1986). It also helps to ensure sustainability of future interventions and commitment by the stakeholders. The community is also assessed for their willingness to adopt proper behaviors for controlling mosquitos which can inform what interventions will be adhered to the most. These techniques help to fill the gaps found in mosquito eradication techniques done in the past. The use of multiple analytical techniques also helps capture the complexity of the mosquito problem and can be used to create better and more grounded policies.

There are a few limitations to this study. The study has a low external validity or low ability to be exactly replicated. This is because the questionnaire was tailored for the target population. There is also a strong likelihood for researcher bias to occur as many questions were open ended and not recorded. Therefore, the quality of the information is reliant on the ability of the research assistants to take down thorough notes while actively being involved in the conversation. This bias also pertains to evaluating in-field observations. Despite efforts to minimize this bias, it is still very likely that it occurred.

There is also a strong likelihood that many observations are underreported, especially factors related to knowledge and practices. This is because many questions called for the respondent to recall their knowledge without much probing or direction from the researcher. Other KAP studies ask very specific questions of respondents leading to more in-depth analysis of a respondent's knowledge and attitudes (Van Bentham *et.al.,* 2002; Acharya et.al., 2005; Shuaib et.al., 2010; Lopchan, 2012; Dihmal *et.al.,* 2014). We were informed previously that open ended questions that prompted conversation were more likely to be accepted by the community. Therefore, it is difficult to ascertain specific KAP scores for respondents in our study and may explain why there was a lack of associations between knowledge and other variables. Although this may have reduced some socially-biased answers, recall-bias would have been much stronger.

The lack of randomization also means that the sample is not statistically representative of the rest of the population. However, the use of mixed methods, multiple data sources, and wide geographical coverage of communities adds validity to our conclusions. Although these limitations can influence the results, the information is still representative of the population and can guide future interventions.

Finally, the study findings were constrained by a lack of time and access. Secondary information was not thoroughly cleaned and assessed for quality while in the field due to lack of time. This strongly influences the validity of the conclusions made based upon this information. There was also a lack of access to information about secondary materials, such as the educational curriculum. Information was not provided on how the materials were designed or what plans were in place for implementation. This also reduced the ability of conclusions to be made from these materials and also reduced conclusion validity.

5. Conclusions

The purpose of this project was to assess the needs of the community in order to provide information, on vector control, that would encourage action and produce outcomes that would be usable by the target population. The employment of CBPR research assisted in achieving this purpose. Results indicated a need for increased education; encouragement of residents to practice more positive behaviors; a need for the community to take leadership and ownership of vector control efforts; increased collaboration among stakeholders; and better methods for intervention evaluation. In addition, this study can be a foundation for future research that will further assist the implementation of vector control efforts. Research should utilize spatial analysis of epidemiological, entomological, and climate related outcomes to better predict future outbreaks. Other topics can go further in depth on the quality of specific interventions and explain further the patterns between location, knowledge, disease, and practice. Both a strength and a weakness of this study is its comprehensive nature.

The study gathered an extensive amount of information about multiple topics in both a quantitative and qualitative manner. This provides a thorough evaluation into the overarching problems with current vector control efforts. However, the study lacks depth when it comes to understanding why certain associations are present. Another issue is the lack of a neutral reference group. The study would have been greatly enhanced had information been collected on the inner Belmopan area as this was perceived as a low risk population.

In the past Belize has demonstrated a strong government will and ability to tackle vector control, especially in regards to malaria. Insecticide use, and government mobilization was sufficient however the current study demonstrates a need for a reevaluation and refocusing of vector control efforts. Government will alone can no longer control mosquitos and potential disease outbreaks in Belmopan, Belize. The key to future control will be to have effective community-based, multifaceted, well planned and evaluated interventions, which is supported by the evidence presented in this study. CBPR approaches and the PRECEDE-PROCEED model can provide a thorough framework for which to plan these interventions. The current study can act as a foundation to assist in guiding these future efforts.

Appendix A

Logistic regression output for knowledge proficiency and sociodemographic characteristics						
Variable	**Odds Ratio**	**Std. Err.**	**z**	**P>z**	**[95% Conf. Interval]**	
Location						
San Martin	Reference	Reference	Reference	Reference	Reference	
Salvapan	0.4960145	0.4583262	-0.76	0.448	0.0810903	3.034029
Maya Mopan	0.2667163	0.2516453	-1.4	0.161	0.0419706	1.694937
Las Flores	0.476786	0.4900736	-0.72	0.471	0.0635916	3.574764
People per household						
1-3	Reference	Reference	Reference	Reference	Reference	
4-6	1.337049	0.9806703	0.4	0.692	0.3175602	5.629483
7 ≤	0.9406466	0.7953527	-0.07	0.942	0.1793507	4.933441
Occupation of respondent						
Various, retired, unemployed	Reference	Reference	Reference	Reference	Reference	
Domestic	6.040373	5.790756	1.88	0.061	0.9226518	39.54483
Government, teacher, student, security, police	19.18508	21.79261	2.6	0.009	2.070483	177.7689
Business, sales, vendor, farmer	2.266268	2.53456	0.73	0.464	0.2531279	20.29001
Carpenter, construction, mason, electrician, mechanic, technician	4.136987	6.456645	0.91	0.363	0.1941797	88.13828
Restaurant, cook staff, janitor, cleaner	1.176847	1.557111	0.12	0.902	0.0879988	15.73849
Occupation of head of household						
Various, retired, unemployed	Reference	Reference	Reference	Reference	Reference	
Domestic	2.864142	2.632993	1.14	0.252	0.4725945	17.35803
Government, teacher, student, security, police	0.3821213	0.3746314	-0.98	0.326	0.055935	2.610469

Business, sales, vendor, farmer	0.7048094	0.6598636	-0.37	0.709	0.1124997	4.415623
Carpenter, construction, mason, electrician, mechanic, technician	0.3151051	0.3507595	-1.04	0.3	0.0355582	2.792359
Restaurant, cook staff, janitor, cleaner	0.5054858	0.6497124	-0.53	0.596	0.0407043	6.277369
Education level of respondent						
None	Reference	Reference	Reference	Reference	Reference	
Primary	0.1370313	0.1621021	-1.68	0.093	0.0134861	1.392369
Secondary	0.0828909	0.1079888	-1.91	0.056	0.0064502	1.065215
Higher	0.0144716	0.0221118	-2.77	0.006	0.0007243	0.2891381
Education level of head of household						
None	Reference	Reference	Reference	Reference	Reference	
Primary	2.035828	2.020284	0.72	0.474	0.2910976	14.23782
Secondary	6.564427	8.08586	1.53	0.127	0.5871009	73.39743
Higher	14.49832	20.52897	1.89	0.059	0.9037624	232.5846
Income						
0-999	Reference	Reference	Reference	Reference	Reference	
1000-1999	0.9145968	0.6336693	-0.13	0.897	0.2352248	3.556119
2000 ≤	6.297521	5.763289	2.01	0.044	1.047556	37.85837
Eldest person living in the household						
19-29	Reference	Reference	Reference	Reference	Reference	
30-39	3.636683	4.032934	1.16	0.244	0.4137684	31.96344
40-49	1.630146	1.81812	0.44	0.661	0.1831773	14.50712
50-59	0.9372773	1.175001	-0.05	0.959	0.0803109	10.9386
60 ≤	0.8254832	1.054823	-0.15	0.881	0.0674562	10.1017
_cons	0.444391	0.82405	-0.44	0.662	0.011732	16.83364

Appendix B

Multivariate model to determine relationship between education and reported sources						
Variable	**RRR**	**Std. Err.**	**z**	**P>z**	**[95% Conf.Interval]**	
No education						
School sources	.2554841	.1657189	-2.1	0.035	0.071653	0.910947
_cons	.3787879	.0889559	-4.13	0	0.239055	0.600199
Primary education			**(base outcome)**			
Secondary education						
School sources	2.311521	.7393138	2.62	0.009	1.234953	4.326583
_cons	.530303	.1108865	-3.03	0.002	0.351996	0.798934
Higher education						
School sources	5.056452	2.398705	3.42	0.001	1.995486	12.81277
_cons	.1212121	.045378	-5.64	0	0.058195	0.252469

Appendix C

Adjusted logistic model to determine association between knowledge proficiency and sources of information						
Variable	**Odds Ratio**	**Std. Err.**	**z**	**P>z**	**[95% Conf. Interval]**	
TV	1.224104	0.668886	0.37	0.711	0.419466	3.572231
Radio	1.008453	0.580999	0.01	0.988	0.326028	3.119302
MOH	4.256376	2.415535	2.55	0.011	1.399506	12.9451
Hospital	1.234785	0.684204	0.38	0.703	0.416806	3.658041
Personal experience and personal research	1.797341	1.059176	0.99	0.32	0.56626	5.704859
Neighbors, family, friends	1.259347	0.757121	0.38	0.701	0.387617	4.091557
School environment	1.588701	0.936931	0.78	0.432	0.500091	5.047022
Respondent has contracted one or more diseases	1.710535	0.959733	0.96	0.339	0.56957	5.137089
Knows a family member who has contracted one or more diseases	3.684498	2.112728	2.27	0.023	1.197542	11.33616
Income						
0-999	Reference	Reference	Reference	Reference	Reference	
1000-1999	0.698362	0.474092	-0.53	0.597	0.1846	2.64198
2000 ≤	4.034419	3.717189	1.51	0.13	0.662995	24.55002
Occupation of the respondent						
Various, retired, unemployed	Reference	Reference	Reference	Reference	Reference	
Domestic	6.447761	6.041958	1.99	0.047	1.027495	40.46116
Government, teacher, student, security, police	21.27924	24.26319	2.68	0.007	2.277153	198.8475
Business, sales, vendor, farmer	2.526144	3.028669	0.77	0.44	0.24095	26.48431

Carpenter, construction, mason, electrician, mechanic, technician	1.664845	2.40741	0.35	0.724	0.097839	28.32916
Restaurant, cook staff, janitor, cleaner	0.649887	0.9368	-0.3	0.765	0.038534	10.96047
Occupation of the head of household						
Various, retired, unemployed	Reference	Reference	Reference	Reference	Reference	
Domestic	2.079428	1.94895	0.78	0.435	0.331248	13.05374
Government, teacher, student, security, police	0.558293	0.544366	-0.6	0.55	0.082584	3.774249
Business, sales, vendor, farmer	0.507578	0.480645	-0.72	0.474	0.079336	3.247411
Carpenter, construction, mason, electrician, mechanic, technician	0.889217	0.901173	-0.12	0.908	0.122	6.481185
Restaurant, cook staff, janitor, cleaner	2.792789	3.608259	0.79	0.427	0.22197	35.13848
Education level of the respondent						
None	Reference	Reference	Reference	Reference	Reference	
Primary	0.0428	0.055598	-2.43	0.015	0.003355	0.545977
Secondary	0.030105	0.040779	-2.59	0.01	0.002117	0.428189
Higher	0.007972	0.0126	-3.06	0.002	0.00036	0.176589
Education level of the head of household						
None	Reference	Reference	Reference	Reference	Reference	
Primary	8.651957	9.653238	1.93	0.053	0.971414	77.0592
Secondary	18.75128	24.04229	2.29	0.022	1.519315	231.427
Higher	35.35673	48.72952	2.59	0.01	2.373149	526.7676
_cons	0.030668	0.043073	-2.48	0.013	0.001955	0.481061

Appendix D

Association epidemiology of respondents and their community of residence						
Variable	**Odds Ratio**	**Std. Err.**	**z**	**P>z**	**[95% Conf. Interval]**	
Location						
San Martin	Reference	Reference	Reference	Reference	Reference	
Salvapan	5.654033	4.726889	2.07	0.038	1.09833	29.1058
Maya Mopan	4.618585	4.013756	1.76	0.078	0.84096	25.3653
Las Flores	7.684212	6.801132	2.3	0.021	1.35587	43.5491
Education level of the respondent						
None	Reference	Reference	Reference	Reference	Reference	
Primary	1.057712	1.042835	0.06	0.955	0.15315	7.3046
Secondary	0.256884	0.281516	-1.24	0.215	0.02998	2.20069
Higher	3.155576	3.885204	0.93	0.351	0.28252	35.2447
Education level of the head of household						
None	Reference	Reference	Reference	Reference	Reference	
Primary	0.988655	0.789449	-0.01	0.989	0.20670	4.72863
Secondary	4.688347	4.770013	1.52	0.129	0.63825	34.4388
Higher	0.178394	0.214631	-1.43	0.152	0.01687	1.88576
Knowledge proficiency	2.620844	1.351969	1.87	0.062	0.95355	7.20336
Income						
0-999	Reference	Reference	Reference	Reference	Reference	
1000-1999	0.355169	0.190908	-1.93	0.054	0.12385	1.01851
2000 ≤	0.462249	0.372248	-0.96	0.338	0.09536	2.24051
Occupation of the respondent						
Various, retired, unemployed	Reference	Reference	Reference	Reference	Reference	
Domestic	0.540848	0.437514	-0.76	0.447	0.11079	2.64026
Government, teacher, student, security, police	0.13781	0.139343	-1.96	0.05	0.01899	0.99988
Business, sales, vendor, farmer	0.386408	0.370563	-0.99	0.321	0.05898	2.53129
Carpenter, construction, mason, electrician,	0.459141	0.566446	-0.63	0.528	0.04090	5.15323

mechanic, technician						
Restaurant, cook staff, janitor, cleaner	0.160108	0.193305	-1.52	0.129	0.01502	1.70649
Occupation of the head of the household						
Various, retired, unemployed	Reference	Reference	Reference	Reference	Reference	
Domestic	1.009423	0.829727	0.01	0.991	0.20155	5.05527
Government, teacher, student, security, police	1.100361	0.95313	0.11	0.912	0.20147	6.00957
Business, sales, vendor, farmer	1.580268	1.346935	0.54	0.591	0.29731	8.39940
Carpenter, construction, mason, electrician, mechanic, technician	1.049173	0.91904	0.05	0.956	0.18846	5.84077
Restaurant, cook staff, janitor, cleaner	0.115846	0.152774	-1.63	0.102	0.00873	1.53608
_cons	0.472975	0.575989	-0.61	0.539	0.04347	5.14553

Appendix E

Adjusted model to determine association between mosquito net use and additional variables						
Variable	**Odds Ratio**	**Std. Err.**	**z**	**P>z**	**[95% Conf. Interval]**	
Respondent has contracted one or more diseases	3.427492	1.813926	2.33	0.02	1.2147	9.67066
Knowledge Proficiency	1.331828	0.689779	0.55	0.58	0.48260	3.67537
Location						
San Martin	Reference	Reference	Reference	Reference	Reference	
Salvapan	0.572065	0.437292	-0.73	0.465	0.12787	2.55924
Maya Mopan	0.765912	0.592193	-0.34	0.73	0.16828	3.48591
Las Flores	0.137008	0.120165	-2.27	0.023	0.02455	0.76436
Education level of the respondent						
None	Reference	Reference	Reference	Reference	Reference	
Primary	2.477637	2.669817	0.84	0.4	0.29978	20.4768
Secondary	2.923135	3.354958	0.93	0.35	0.30825	27.7201
Higher	0.476545	0.627258	-0.56	0.573	0.03611	6.28792
Education level of the head of household						
None	Reference	Reference	Reference	Reference	Reference	
Primary	2.415906	2.164182	0.98	0.325	0.41741	13.9827
Secondary	1.014421	1.029414	0.01	0.989	0.13881	7.4131
Higher	3.870696	4.918282	1.07	0.287	0.32078	46.7051
Occupation of the respondent						
Various, retired, unemployed	Reference	Reference	Reference	Reference	Reference	
Domestic	0.381729	0.313672	-1.17	0.241	0.07626	1.91072
Government, teacher, student, security, police	0.184786	0.182333	-1.71	0.087	0.02671	1.27812
Business, sales, vendor, farmer	0.354716	0.342833	-1.07	0.284	0.05335	2.35812
Carpenter, construction, mason, electrician, mechanic, technician	0.246352	0.284486	-1.21	0.225	0.02562	2.36874

Restaurant, cook staff, janitor, cleaner	2.009726	2.279189	0.62	0.538	0.21767	18.5552
Occupation of the head of the household						
Various, retired, unemployed	Reference	Reference	Reference	Reference	Reference	
Domestic	1.007597	0.806681	0.01	0.992	0.20980	4.83902
Government, teacher, student, security, police	4.462531	3.926018	1.7	0.089	0.79564	25.0291
Business, sales, vendor, farmer	1.516773	1.284496	0.49	0.623	0.28845	7.97572
Carpenter, construction, mason, electrician, mechanic, technician	3.25814	2.726322	1.41	0.158	0.63198	16.7970
Restaurant, cook staff, janitor, cleaner	0.434791	0.521405	-0.69	0.487	0.04144	4.56086
Income						
0-999	Reference	Reference	Reference	Reference	Reference	
1000-1999	0.83188	0.453066	-0.34	0.735	0.28607	2.41907
2000 ≤	0.316517	0.255355	-1.43	0.154	0.06511	1.53857
_cons	0.583441	0.668498	-0.47	0.638	0.06175	5.51176

Appendix F

Presence of shade tree and location association: adjusted model						
Variable	**Odds Ratio**	**Std. Err.**	**z**	**P>z**	**[95% Conf.Interval]**	
Location						
San Martin	Reference	Reference	Reference	Reference	Reference	
Salvapan	12.93909	13.17596	2.51	0.012	1.758411	95.21105
Maya Mopan	25.88463	27.58815	3.05	0.002	3.204949	209.0561
Las Flores	8.27377	8.638292	2.02	0.043	1.069055	64.03345
Education level of the respondent						
None	Reference	Reference	Reference	Reference	Reference	
Primary	1.591836	1.723078	0.43	0.668	0.190774	13.28246
Secondary	0.998407	1.109511	0	0.999	0.11308	8.815186
Higher	0.288294	0.353339	-1.01	0.31	0.026097	3.184823
Education level of the head of household						
None	Reference	Reference	Reference	Reference	Reference	
Primary	0.175426	0.161114	-1.9	0.058	0.028996	1.061331
Secondary	0.107245	0.117126	-2.04	0.041	0.012611	0.912028
Higher	0.270554	0.326061	-1.08	0.278	0.025493	2.871349
Knowledge Proficiency	4.03259	2.224517	2.53	0.011	1.367829	11.88876
Income						
0-999	Reference	Reference	Reference	Reference	Reference	
1000-1999	1.677215	0.932938	0.93	0.353	0.563786	4.989571
2000 ≤	1.683751	1.420076	0.62	0.537	0.322385	8.793893
Occupation of the respondent						
Various, retired, unemployed	Reference	Reference	Reference	Reference	Reference	
Domestic	0.749905	0.622034	-0.35	0.729	0.147553	3.811225
Government, teacher, student, security, police	0.80156	0.736659	-0.24	0.81	0.132329	4.855316
Business, sales, vendor, farmer	0.189786	0.201247	-1.57	0.117	0.02375	1.516585
Carpenter, construction, mason, electrician, mechanic, technician	0.177252	0.23276	-1.32	0.188	0.013515	2.324628
Restaurant, cook staff, janitor, cleaner	1.149839	1.267639	0.13	0.899	0.132505	9.977995

Occupation of the head of the household						
Various, retired, unemployed	Reference	Reference	Reference	Reference	Reference	
Domestic	0.906097	0.766922	-0.12	0.907	0.172471	4.760281
Government, teacher, student, security, police	0.459866	0.403863	-0.88	0.376	0.082241	2.571415
Business, sales, vendor, farmer	0.726562	0.65764	-0.35	0.724	0.123258	4.282817
Carpenter, construction, mason, electrician, mechanic, technician	5.067914	4.786229	1.72	0.086	0.796048	32.26408
Restaurant, cook staff, janitor, cleaner	0.393603	0.479317	-0.77	0.444	0.036182	4.281775
_cons	0.169955	0.230277	-1.31	0.191	0.01194	2.419082

Presence of stagnant water and location association: adjusted model						
Variable	**Odds Ratio**	**Std. Err.**	**Z**	**P>z**	**[95% Conf.Interval]**	
Location						
San Martin	Reference	Reference	Reference	Reference	Reference	
Salvapan	1.991916	1.50772	0.91	0.363	0.451836	8.781362
Maya Mopan	9.812864	8.079444	2.77	0.006	1.954146	49.27589
Las Flores	1.118878	0.894484	0.14	0.888	0.233503	5.36134
Education level of the respondent						
None	Reference	Reference	Reference	Reference	Reference	
Primary	3.296951	3.446872	1.14	0.254	0.424819	25.58707
Secondary	2.939639	3.169424	1	0.317	0.355268	24.32385
Higher	1.939315	2.324682	0.55	0.581	0.185056	20.32332
Education level of the head of household						
None	Reference	Reference	Reference	Reference	Reference	
Primary	0.870996	0.710023	-0.17	0.865	0.17625	4.304304
Secondary	0.543678	0.525718	-0.63	0.529	0.081707	3.617634
Higher	1.585486	1.682236	0.43	0.664	0.198161	12.68546
Knowledge proficiency	0.586899	0.299446	-1.04	0.296	0.215906	1.595369
Income						
0-999	Reference	Reference	Reference	Reference	Reference	
1000-1999	1.064952	0.573193	0.12	0.907	0.370839	3.058265
2000 ≤	2.045127	1.574983	0.93	0.353	0.452061	9.252162
Occupation of the respondent						

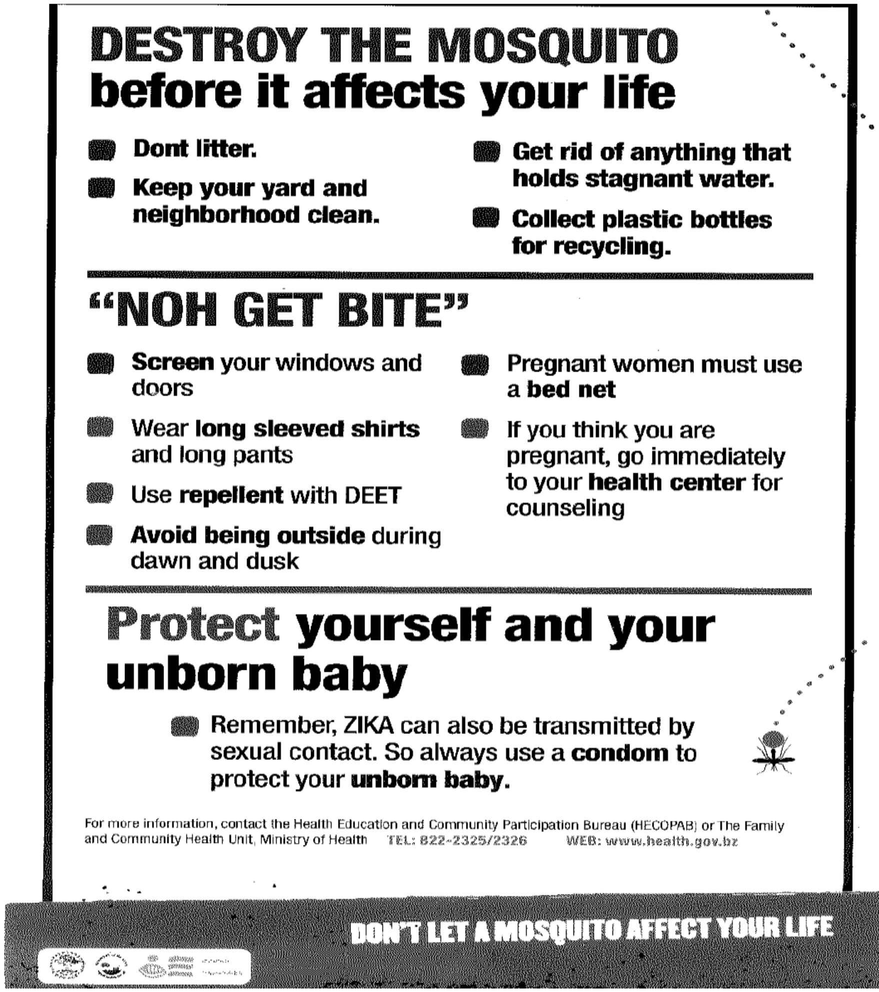
Various, retired, unemployed	Reference	Reference	Reference	Reference	Reference	
Domestic	0.870931	0.720086	-0.17	0.867	0.17227	4.403089
Government, teacher, student, security, police	0.773581	0.71178	-0.28	0.78	0.12744	4.695755
Business, sales, vendor, farmer	0.629204	0.613326	-0.48	0.635	0.093126	4.251218
Carpenter, construction, mason, electrician, mechanic, technician	0.283716	0.35466	-1.01	0.314	0.024482	3.287983
Restaurant, cook staff, janitor, cleaner	4.197373	4.974456	1.21	0.226	0.411328	42.83185
Occupation of the head of the household						
Various, retired, unemployed	Reference	Reference	Reference	Reference	Reference	
Domestic	2.17031	1.758293	0.96	0.339	0.443521	10.62011
Government, teacher, student, security, police	0.375994	0.325411	-1.13	0.258	0.068943	2.050541
Business, sales, vendor, farmer	1.314663	1.060909	0.34	0.735	0.27034	6.393198
Carpenter, construction, mason, electrician, mechanic, technician	2.282184	1.918441	0.98	0.326	0.439356	11.85453
Restaurant, cook staff, janitor, cleaner	4.898087	6.544003	1.19	0.234	0.357103	67.183
_cons	0.125401	0.145395	-1.79	0.073	0.012924	1.216791

Presence of potential mosquito breeding sites and location association: adjusted model

Variable	Odds Ratio	Std. Err.	z	P>z	[95% Conf.Interval]	
Location						
San Martin	Reference	Reference	Reference	Reference	Reference	
Salvapan	0.085787	0.070116	-3	0.003	0.017287	0.425725
Maya Mopan	0.164985	0.138648	-2.14	0.032	0.031778	0.856575
Las Flores	0.105693	0.090801	-2.62	0.009	0.019624	0.569262
Education level of the respondent						
None	Reference	Reference	Reference	Reference	Reference	
Primary	0.964312	1.00206	-0.03	0.972	0.125805	7.391608
Secondary	1.898809	2.091585	0.58	0.56	0.219211	16.44753
Higher	1.98868	2.483825	0.55	0.582	0.171961	22.99852
Education level of the head of household						
None	Reference	Reference	Reference	Reference	Reference	
Primary	0.481946	0.391282	-0.9	0.369	0.098158	2.366304
Secondary	0.762592	0.73997	-0.28	0.78	0.113852	5.107904
Higher	0.615502	0.68331	-0.44	0.662	0.069864	5.422568
Knowledge proficiency	3.132368	1.609388	2.22	0.026	1.144278	8.574602
Income						
0-999	Reference	Reference	Reference	Reference	Reference	
1000-1999	1.165053	0.610563	0.29	0.771	0.41712	3.254096
2000 ≤	0.279712	0.219792	-1.62	0.105	0.059959	1.304873
Occupation of the respondent						
Various, retired, unemployed	Reference	Reference	Reference	Reference	Reference	
Domestic	0.465674	0.372368	-0.96	0.339	0.097148	2.232187
Government, teacher, student, security, police	1.880643	1.73642	0.68	0.494	0.30788	11.48765
Business, sales, vendor, farmer	1.210967	1.132407	0.2	0.838	0.19371	7.570302
Carpenter, construction, mason, electrician, mechanic, technician	0.689777	0.835507	-0.31	0.759	0.064221	7.408732
Restaurant, cook staff, janitor, cleaner	0.780183	0.814144	-0.24	0.812	0.100912	6.031847

Occupation of the head of the household						
Various, retired, unemployed	Reference	Reference	Reference	Reference	Reference	
Domestic	2.395172	1.901838	1.1	0.271	0.505193	11.35576
Government, teacher, student, security, police	1.672779	1.442211	0.6	0.551	0.308718	9.063889
Business, sales, vendor, farmer	2.239111	1.88719	0.96	0.339	0.429198	11.68137
Carpenter, construction, mason, electrician, mechanic, technician	0.737986	0.618675	-0.36	0.717	0.142712	3.81623
Restaurant, cook staff, janitor, cleaner	1.754729	2.012782	0.49	0.624	0.185281	16.61845
_cons	4.542303	5.13224	1.34	0.18	0.496048	41.59379

Appendix G



DESTROY THE MOSQUITO before it affects your life

- **Dont litter.**
- **Keep your yard and neighborhood clean.**
- **Get rid of anything that holds stagnant water.**
- **Collect plastic bottles for recycling.**

"NOH GET BITE"

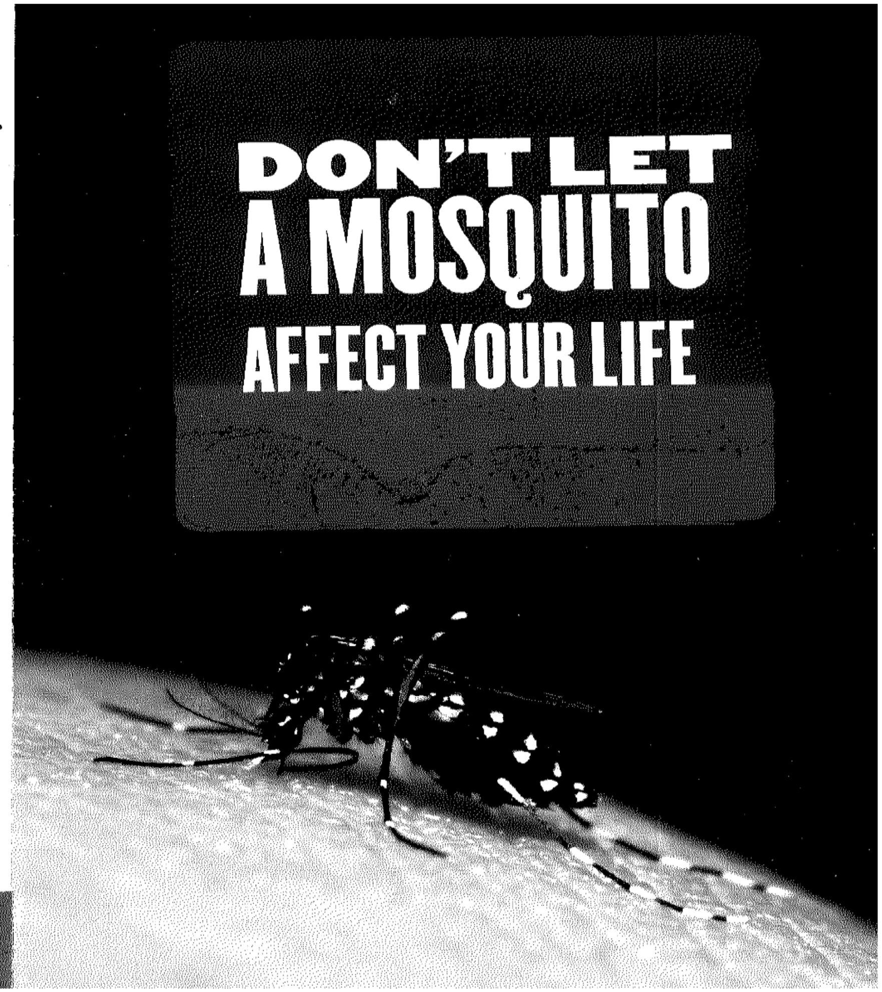
- **Screen** your windows and doors
- Wear **long sleeved shirts** and long pants
- Use **repellent** with DEET
- **Avoid being outside** during dawn and dusk
- Pregnant women must use a **bed net**
- If you think you are pregnant, go immediately to your **health center** for counseling

Protect yourself and your unborn baby

- Remember, ZIKA can also be transmitted by sexual contact. So always use a **condom** to protect your **unborn baby.**

For more information, contact the Health Education and Community Participation Bureau (HECOPAB) or The Family and Community Health Unit, Ministry of Health TEL: 822-2325/2326 WEB: www.health.gov.bz

DON'T LET A MOSQUITO AFFECT YOUR LIFE



Mosquitoes transmit many diseases. ZIKA is one of the worst.

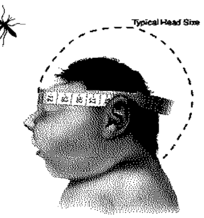
Common Symptoms of Zika are:

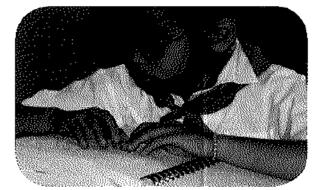
- High Fever
- Rash
- Conjunctivitis (Pink Eye)
- Joint and muscle pain
- Headache

and you may not be able to work for weeks

DON'T LET A MOSQUITO AFFECT YOUR LIFE

When a PREGNANT WOMAN gets infected with ZIKA, the biggest threats to her unborn baby are:





- **Microcephaly**
  Babies born with an abnormally small head and brain and will never develop into a normal child. They will need to receive special care for the rest of their lives.
- **Other birth defects**
  Such as blindness and impaired growth.

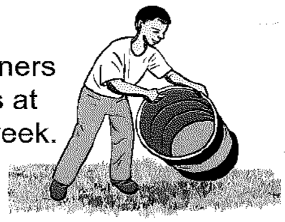
- **Guillain-barré syndrome**
  A neurological disorder in which people will need life-long rehabilitation.

Protecting pregnant women and their unborn babies MUST be our biggest concern.

DON'T LET A MOSQUITO AFFECT YOUR LIFE

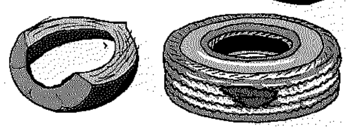
TO PREVENT DENGUE, ELIMINATE THE MOSQUITO

1. Wash water storage containers such as drums at least once a week.

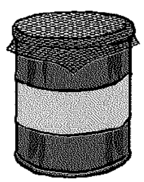


2. Change the water in flower pots every 4 or 5 days.

3. Avoid having containers that can collect water and become mosquito breeding sites in your yard.



4. Keep vats, drums, buckets and all other containers that can collect water properly covered.



PREVENT DENGUE

If every family eliminates mosquito breeding sites which exist in and around their homes, Dengue can be avoided.

Vector Control Program
Ministry of Health
Belize, C.A.
2007
Tel: 822-2325, 822-2363

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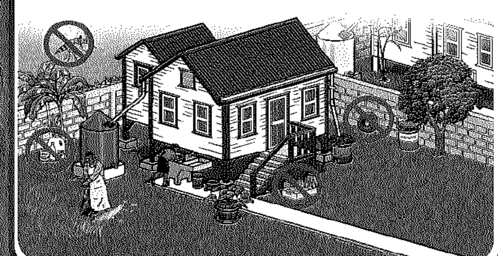
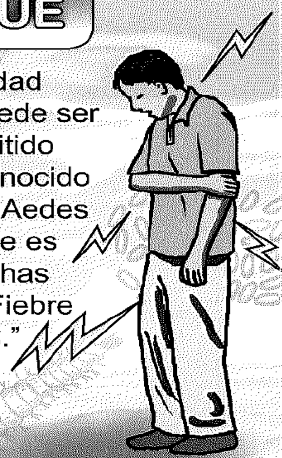
PREVENT DENGUE

BY ELIMINATING THE "BLACK & WHITE STRIPED" (*Aedes aegypti*) MOSQUITO



EL DENGUE



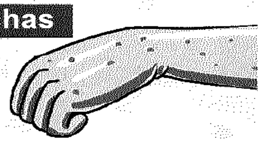
Es una enfermendad infecciosa que puede ser mortal. Es transmitido por el zancudo conocido con el nombre de Aedes aegypti. El Dengue es conocido por muchas personas como "Fiebre Quebrantahuesos."

SIGNOS Y SINTOMAS

Fiebre Alta

Dolor de Cabeza

Ronchas



Joint and muscle pain Retro-orbital pain (pains behind eyes)

¿QUE HACER?

Si usted presenta alguno de esos síntomas.

1. Acuda al establecimiento de salud más cercano.
2. Baje la fiebre; para el niño, acetaminofen infantil y para adultos, acetaminofen.
3. No tome medicamentos que contengan aspirina, porque éstos agravan la enfermedad.
4. Tome bastantes líquidos y repose.

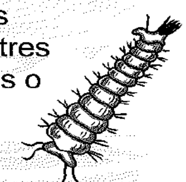
¿COMO SE TRANSMITE?

Se transmite cuando el zancudo pica a una persona enferma de Dengue y luego va a picar a una persona sana.

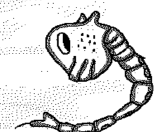
¿COMO SE REPRODUCE... EL ZANCUDO?

- La hembra deposita sus huevos en depósitos con agua: barriles, pilas, llantas, etc.

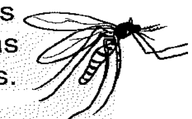
- Si no se eliminan los huevos, a los dos o tres días nacen las larvas o cabezones.

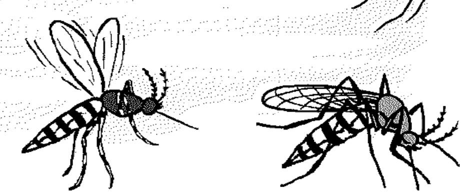


- Si no se eliminan las larvas, a los 6 u 8 días éstas se convertiran en pupas.



- Y si no se eliminan las pupas, a los 2 ó 3 días nacerán los zancudos.





Appendix H

DAILY AEDES AEGYPTI CHECK PREMISES FORM

CAYO DISTRICT LOCATION________ AREA:________ INSPECTOR:________ DATE:________

STREET OR ROAD	HOUSE HOLD NUMBER	NO. CLOSED	POSITIVE	NO CISTERN	WET	POSITIVE	NO. DRUMS	WET	POSITIVE	NO. VASE	WET	POSITIVE	NO. BUCKET	WET	POSITIVE	NO. TYRES	WET	POSITIVE	NO. CARS, BOTTLES	WET	POSITIVE	NO. CAR PARTS	WET	POSITIVE	NO. COCUNUT SHELL	WET	POSITIVE	NO. TREE HOLE	WET	POSTIVE	NO. WATERING PANS	WET	POSITIVE	OTHER CONTAINERS	WET	POSITIVE	TOTAL # Positive containers	Signature of Household
TOTAL																																						

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