Public Health Recommendations for the Control of Arboviral Diseases in the Caribbean

by

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Abstract

Mosquito-borne viral (arboviral) infections, such as dengue, chikungunya, and Zika, are of significant public health importance in the Caribbean. These viruses cause significant morbidity in affected communities. Further, arboviral outbreaks can affect economies due to their prevalence in the tourist-based economic Caribbean. Currently, these viruses do not have therapeutic treatments or licensed vaccines to prevent infection. As such, the best prevention measures involve an aspect of integrated vector management, community participation in source reduction of mosquito breeding sites and individuals following measures for protection from biting mosquitoes.

Mosquito Awareness Week, a yearly program supported by the Pan American Health Organization, aims to build community capacity by supporting participating countries in providing their communities with education in mosquito control and arboviral diseases prevention methods. Building off of the reported activities by participating countries, this paper gives public health recommendations for future Mosquito Awareness Week programs as well as general recommendations for mosquito control and arboviral diseases prevention in the Caribbean. Included in the recommendations are to improve surveillance systems, ensure the incorporation of the community in source reduction activities so as to build capacity, developing methods for

assessing retention of educational materials, strengthening the healthcare system, and ensuring transparent communication.

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Preface

Acknowledgments

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List of Acronyms

ADE … Antibody-dependent enhancement

BVI … British Virgin Islands

CARPHA … Caribbean Public Health Agency

CARICOM … Caribbean Community

CDC … Centers for Disease Control and Prevention

CHIKV … Chikungunya virus

DENV … Dengue virus

E … Envelope protein

ECC … Eastern Caribbean countries

EHO … Environmental Health Officers

ELISA… Enzyme-linked immunosorbent assay

FD … French Department of the Americas

FDA …Food and Drug Administration

GBS … Guillain-Barré syndrome

GDP … Gross Domestic Product

GIS … Geographic Information System

GM … Genetically modified

IVM … Integrated vector management

KAP … Knowledge, attitudes, and practices

MAW … Mosquito Awareness Week

MoH … Ministry of Health

NGO … Non-governmental organization

NIAID … National Institute of Allergy and Infectious Diseases

NIH … National Institutes of Health

NSAIDS … non-steroidal anti-inflammatory drugs

NS-1 …Non-structural protein

PAHO … Pan American Health Organization / World Health Organization

PCR … Polymerase chain reaction

PLISA … PAHO’s Health Information Platform for the Americas

PrM … Pre-membrane protein

PRNT … Plaque reduction neutralization test

rRT-PCR … Reverse real-time polymerase chain reaction

U.S. … United States of America

VC … Vector Control

VCO … Vector Control Officers

WHO … World Health Organization

WRAID … Walter Reed Army Institute of Research

YFV…Yellow Fever virus

ZIKV … Zika virus

1.0 Background and Early Mosquito Eradication Efforts

Mosquito-borne diseases, such as dengue, chikungunya, Zika, yellow fever, and malaria are all of public health importance to the Americas region. The early 20th century malaria and *Aedes aegypti* eradication programs primarily used larval and adult insecticides, as well as quarantining active cases and surveillance of ports, led to the eradication of malaria and yellow fever in 1962-1964 in the Caribbean and through most of the Americas region. (Brathwaite, et al., 2012; Klitting, et al., 2018; Webb, 2016) Due to the successful elimination of the malaria parasite and the Yellow Fever virus (YFV), these are less of a concern in the Caribbean, except for Hispaniola island, where malaria is still endemic and Haiti still has a poor surveillance system. Although, there are instances of imported malaria cases into the non-endemic Caribbean, which is a concern due to the already present mosquito vector. (PAHO, 2016c, 2017) For example, Jamaica had a malaria outbreak in 2006-2009, the first since 1966, that started from imported cases from Haitian refugees. (PAHO, 2016c; WHO, 2017) This highlights the need for robust and vigilant surveillance systems.

Starting in the 1960's, gains from the successful vector eradication campaigns throughout most of the Americas in the early to mid 20th century were quickly lost despite continued efforts and commitment from the Pan American Health Organization / World Health Organization (PAHO). As countries deemed eradication programs successful, there was a lack of continued political will along with the decline in surveillance systems which could not detect small re-infestations. This led to a slow response to re-infestations. Furthermore, rapidly growing urban spaces with a lack of proper and sufficient environmental sanitation and then the evermore common domestic and international travel facilitated mosquito re-introduction and spread.

Additionally, mosquito resistance to insecticides used in the early 20th century, insufficient community participation, and the high cost of materials for eradication and thus less government participation to join in with other country's programs further lead to the decline in early eradication program effectiveness. (Brathwaite, et al., 2012)

Regarding yellow fever, there is an effective and safe vaccine that has been available since 1951. (Klitting, et al., 2018) Further, the World Health Organization (WHO) recommends a yellow fever vaccination coverage of at least 80% to prevent large outbreaks. (WHO, 2019b) Yellow fever vaccination rates in Trinidad and Tobago has ranged from 85-96% from 2011-2018. No other Caribbean country reported yellow fever vaccination rates. (WHO, 2019d) Trinidad and Tobago are the closest islands to mainland South America where Brazil has had a YFV outbreak as recently as 2016. Additionally, many of the countries bordering the Caribbean as well as the Caribbean island states require yellow fever vaccinations for travelers from endemic areas. (CDC, 2019a; Klitting, et al., 2018) The U.S.'s Centers for Disease Control and Prevention (CDC), does not recommend a yellow fever vaccination for American travelers to most of the Caribbean region due to the low transmission risk. (CDC, 2018)

Importantly, many Caribbean countries have the mosquito vector for transmitting both malaria and yellow fever along with non-human primates susceptible to YFV and thus a concern for re-introduction. (Klitting, et al., 2018) Moreover, with climate change facilitating expanding locations for already present mosquito vectors, population migration (due to numerous reasons) from endemic areas, unplanned urban growth, and water and sanitation problems, all contributes to the concern for malaria and yellow fever reintroduction and further highlights the need for strong and continued surveillance and proper YFV vaccination coverage. (Paupy, et al., 2009; WHO, 2017) Along with vector control (VC) methods, prevention methods such as malaria chemoprophylaxis and a safe and effective yellow fever vaccine continue to help protect those in the Caribbean. Conversely, there currently are no specific treatments (just supportive treatment of symptoms) or medically preventable methods such as vaccines available for dengue, chikungunya, or Zika and these arthropod-borne viruses (arboviral diseases) are of significant importance to the Caribbean due to their high levels of morbidity. (Brathwaite, et al., 2012; Paupy, et al., 2009; Webb, 2016)

Figure 1 Map of the Caribbean. Islands labeled in red indicate independent island countries.

Source: WorldAtlas

1.1 Dengue Virus (DENV)

Based on clinical and epidemiological descriptions, dengue has been suspected in the Americas and specifically the Caribbean (Martinique and Guadeloupe) since 1635, brought by the slave trade from Africa. (Brathwaite, et al., 2012; Simmons, et al., 2012). Dengue typically has an endemo-epidemic pattern of outbreaks occurring every 3-5 years that has eventually led to an endemic status since the 1990s in the Caribbean. Microbiological (and then serological) verification of outbreaks did not occur until 1943. (Brathwaite, et al., 2012) There are four distinct serotypes of the dengue virus, DENV-1, DENV-2, DENV-3, and DENV-4 and multiple serotypes can circulate in a country and during an outbreak. (Brathwaite, et al., 2012; Clapham, et al., 2017; Guzman, et al., 2010) The four serotypes share about 65% of their genome, yet they cause nearly identical symptomology and similar ecological niches. (Guzman, et al., 2010) By the mid-20th century only DENV-2 was circulating in the Americas. With every decade another serotype was identified as circulating starting with DENV-3, then DENV-1, and lastly DENV-4 by 1981. Additionally, with every decade there was also a noticeable increase in the number of cases (about 1 million in the 1980s to 4.7 million in the 2000s) and an increase in the number of countries affected indicating the resurgence and spread of Aedes mosquitoes. (Brathwaite, et al., 2012)

In the Americas, humans are the reservoir for the dengue virus, a Flavivirus, which is spread by the vector Aedes aegypti and less frequently by the Aedes albopictus mosquito. (Paupy, et al., 2009, 2010; Simmons, et al., 2012) These mosquitoes also spread chikungunya, Zika, and yellow fever, of which everyone is at risk of varying degree dependent on the region's rainfall, temperature, and environmental sanitation. (Brathwaite, et al., 2012; Tjaden, et al., 2013; Webb, 2016; WHO, 2019a)

Severe dengue was first recognized in the 1950s and remains the leading cause of hospitalization and death among children and adults in Latin America. (WHO, 2019a) For travelers returning from low- and middle-income countries, malaria followed by dengue are the most diagnosed causes for a fever. (WHO, 2019a) After recovering from an infection, there is long-lived immunity to that serotype but not great protectivity to the other serotypes, thus subsequent dengue infections can increase the risk of severe dengue. (Calisher, et al., 1989; Simmons, et al., 2012) This temporary cross-protection led to the endemo-epidemic pattern. (Clapham, et al., 2017) Also, as maternal antibodies can be transferred through the placenta and in breast milk, leading to temporary cross-protection in infants. At about 6-12 months of age when the maternal antibodies wane in the infant, there is a risk for severe dengue. (Arragain, et al., 2017; Basurko, et al., 2018) Severe dengue is thought to be caused by antibody-dependent enhancement (ADE). This is due to non-neutralizing antibodies from a previous infection, or for infants the lower concentration of maternal antibodies during the infection, facilitating uptake of the virus. (Guzman, et al., 2010; Weaver, et al., 2018) Additionally, the severity of subsequent infections in adults increases from month-to-month during outbreaks on islands and/or with a longer interval between infections. (Guzman, et al., 2010; Simmons, et al., 2012)

It is estimated that the majority (about 75%) of illnesses are asymptomatic and as such, there is probably underreporting and misclassification occurring. (Clapham, et al., 2017; Simmons, et al., 2012; Duong, et al., 2015) Further, this leads to silent virus transmission to mosquitoes and thus more widespread disease transmission due to asymptomatic individuals being able to keep to daily routines compared to symptomatic individuals staying more localized at home or in the hospital. (Duong, et al., 2015; Nguyet, et al., 2013) Also, the silent viral transmission and asymptomatic infections can contribute to persistent circulation. Moreover, with insufficient surveillance systems there is the possibility of delayed detection of outbreaks. (Duong, et al., 2015)

With an incubation period of 3-10 days after a bite from an infected mosquito, an estimated 25% of dengue infected people will have symptoms for 2-7 days ranging from a mild to high-grade, febrile illness (40°C/104°F) with joint pain and/or severe headache to severe and life threatening illness. (Guzman, et al., 2010; Simmons, et al., 2012; Waggoner, et al., 2016; Weaver, et al., 2018) An estimated 5% of cases become severe dengue, a hemorrhagic shock which can lead to death, and requires proper and prompt medical intervention for 24-48 hours which can reduce the number of deaths due to severe dengue from more than 10% to less than 1%. (Guzman, et al., 2010; Simmons, et al., 2012) Severe dengue is mainly reported in children and young adults due to ADE. (Weaver, et al., 2018) To accomplish the reduction in severe dengue deaths, proper case management is necessary and can be obtained through country level capacity building. (Guzman, et al., 2010; Weaver, et al., 2018) Further, due to the risk of progressing to severe dengue, it is recommended to not take non-steroidal anti-inflammatory drugs (NSAIDs, i.e., aspirin and ibuprofen) as they can worsen hemorrhaging. (Simon, et al., 2015) Specific to pregnant women, being viremic during pregnancy, more so during late pregnancy and intrapartum, can cause maternal-fetal transmission. (Arragain, et al., 2017; Basurko, et al., 2018) Additionally, the virus is transmitted through breast milk and through the placenta. (Arragain, et al., 2017; Basurko, et al., 2018) Further, neonates can have the same severe symptoms seen in children and adults around one week of life for perinatal infected infants. (Arragain, et al., 2017; Basurko, et al., 2018)

1.2 Chikungunya virus (CHIKV)

Based on clinical symptoms described, it is believed that a "dengue" outbreak in 1827 on St. Thomas island in the US Virgin Islands, which then spread to the rest of the Caribbean and parts of the United States of America (U.S.) and Mexico, was actually the true introduction of Chikungunya virus to the Americas. Like for dengue, it is believed CHIKV was brought to the Americas via the African slave trade. (Brathwaite, et al., 2012; Yactayo, et al., 2016) As the 1827 outbreak cannot be proven microbiologically or serologically, what is considered the first documented autochthonous case of chikungunya in the Americas occurred on the French side of the Caribbean island, St. Martin in December 2013. (PAHO, n.d. e; Yactayo, et al., 2016) At that time, St. Martin had a concomitant dengue outbreak and many chikungunya cases were mislabeled as dengue as they have similar symptoms. (Yactayo, et al., 2016) Once introduced in St. Martin, chikungunya quickly spread throughout the Caribbean. (PAHO, 2016d) As of now, there are no nonhuman primate reservoir in the Americas, only in Africa. (ECDC, n.d.; Weaver, et al., 2018) As the reemergence of chikungunya in the Americas is so recent, there is a need to determine if there are any nonhuman primates and other vertebrates in the Americas that are susceptible and/or can become a reservoir. (Weaver, et al., 2018; Yactayo, et al., 2016) If so, *Aedes albopictus* mosquitoes, which are known to transmit the virus can lead to sylvatic and not just urban transmission such as with YFV. (CDC, 2018; Weaver, et al., 2016)

Chikungunya virus is an *Alphavirus* spread by the vectors *Aedes aegypti* and *Aedes albopictus* mosquitoes. (Paupy, et al., 2009, 2010; Powers, 2017) CHIKV can also be spread via accidental exposure to viremic blood and vertical transmission through intrapartum. (Simon, et al., 2015) About 3% - 28% of cases are asymptomatic and as such there could be underreporting occurring. (Simon, et al., 2015; Weaver, et al., 2018) Those that do have symptomatic illness, typically after a 3-7 day incubation period after being bitten by an infected mosquito, develop a sudden high fever (over 39 °C/102 °F) and severe joint pain, followed by a rash over the majority of the body. These symptoms can last 7-10 days. (Mehta, et al., 2018; Simon, et al., 2015; Waggoner, et al., 2016; Yactayo, et al., 2016) Symptoms of non-severe DENV infections are similar to those of chikungunya although the joint pain is more intense and more localized to the joints in CHIKV infections. (Weaver, et al., 2018; PAHO, n.d. e) Therefore differential diagnosis is critical, as NSAIDs can help alleviate the joint pains from CHIKV but are contraindicated if DENV is suspected. (Simon, et al., 2015) Additionally, the arthritis can last for months or years and is more apparent in patients over 35 years. (Weaver, et al., 2018) More serious complications such as ocular disease, hepatitis, Guillain-Barré syndrome, and myocarditis are rare and if they occur, it is typically seen more in the higher risk populations such as those over 65 years of age, neonates exposed intrapartum, and those with chronic diseases such as diabetes, heart disease or hypertension. (Simon, et al., 2015; Tomashek, et al., 2017; Weaver, et al., 2018; Yactayo, et al., 2016)

Guillain- Barré syndrome (GBS) is an autoimmune polyradiculoneuropathy that is triggered 2-8 weeks after an infection. GBS is characterized by progressive weakness in the extremities, motor dysfunction, paralysis, reduced or absent tendon reflexes, and possibly cranial nerve disorders. (Weaver, et al., 2016, 2018; Yuki, et al., 2012) Fatality to CHIKV infections is also rare (0-4%) and when it occurs it typically is older adults who are at higher risk. (Weaver, et al., 2018) Unique to chikungunya infections, is about 5% - 80% of patients will have a relapse of rheumatologic symptoms about 20 months after initial symptoms subsist and can last for months or years. (Yactayo, et al., 2016)

Interestingly, CHIKV is not neurotropic, but it does infect the meninges and can be found in the cerebrospinal fluid. (Weaver, et al., 2018) Specific to pregnant women, the virus does not cross the placenta and the highest risk of maternal-fetal transmission (about 50%) is being viremic during intrapartum which may cause neonatal complications such as myocardial disease, hemorrhaging, acute respiratory failure, and neurological disease, but studies have not found CHIKV in breast milk. (Simon, et al., 2015; Weaver, et al., 2018) Of note, there have been a rare number of reports of spontaneous abortions following maternal CHIKV infections. (Simon, et al., 2015; Weaver, et al., 2018; ECDC, n.d.) Once a person recovers from the acute phase they will have life-long immunity to chikungunya. (ECDC, n.d.)

1.3 Zika virus (ZIKV)

In the Americas region, there was no evidence of Zika prior to 2014. (Weaver, et al., 2016) In late 2014, clusters of cases of fever, rash, headache, and muscle and joint pain were noticed in Northeastern Brazil which rapidly spread to the entire country by late 2015. (Weaver, et al., 2016) The first Caribbean Zika autochthonous case was in Martinique in December of 2015 which then spread to other Caribbean countries throughout 2016. (PAHO, 2016b, 2018a) In late 2015, months after the outbreak began in Brazil, a higher than usual number of microcephaly in infants in Brazil and in French Polynesia lead to the WHO's declaration of Public Health Emergency of International Concern in early 2016. (Weaver, et al., 2016; PAHO, 2016b) Also in early 2016, the United States of America reported the first confirmed case of sexually transmitted ZIKV. (PAHO, 2016b) Although, sexual transmission of ZIKV was first implicated in 2008 when scientists returning home from their research site in Senegal, known to be endemic for ZIKV, became sick and spread to his wife but not his children, thus ruling out direct contact as a transmission route. (Foy, et al., 2011)

An experimental study in 1952 showed ZIKV to be neurotropic in mice. (Kindhauser, et al., 2016) Yet the mild, self-limiting infections in Africa and Asia may be due to the endemic nature, where the infections and thus immunity occurs prior to child-bearing age. As such microcephaly and GBS are not seen or they have such a low incidence it's cause was unrecognized. (Weaver, et al., 2016) Additionally, ZIKV infections in Africa and Asia were rare and benign with no deaths, hospitalizations, hemorrhagic complications, or neurologic complications and seroprevalence studies determined widespread human exposure. (Kindhauser, et al., 2016) Conversely, in a naïve population, such as on Yap Island in 2007 and the Americas region in 2015, there is a lack of population immunity leading to more cases of microcephaly and GBS. (Kindhauser, et al., 2016; Weaver, et al., 2016)

Accurate Zika virus data in the Americas is not available from early in the outbreak as Zika was not a mandatory reported infection. Thus, much of the knowledge today regarding the association of microcephaly and GBS to ZIKV was determined with numerous retrospective studies. (PAHO, 2016b; de Oliveira, et al., 2017; Weaver, et al., 2016; WHO, 2018a) Additionally, the naïve monkeys in the Americas and the lack of monkeys on Yap Island indicates the start of those outbreaks are most likely due to mosquitoes. (Gregory, et al., 2017; Kindhauser, et al., 2016; Weaver, et al., 2016) Further, due to the enzootic nature of Zika in Africa, there is a need for strong surveillance as well as more research to determine if New World nonhuman primates can act as a reservoir. If so, *Aedes albopictus* mosquitoes, which are known to transmit the virus can lead to sylvatic and not just urban transmission such as with YFV. (CDC, 2018; Weaver, et al., 2016)

Zika virus is a *Flavivirus* spread by *Aedes aegypti* and *Aedes albopictus* mosquitoes, as well as through perinatal, sexual, and transplacental transmission (breastfeeding has not been established as a source of transmission). (Gregory, et al., 2017; Foy, et al., 2011) About 50%-80% of all cases are asymptomatic and thus there may be underdiagnosis. Symptomatic cases are typically mild, self-limited illness such as fever, rash, conjunctivitis, and joint pain and thus it is easy for ZIKV to be misdiagnosed. (Grossi-Soyster, et al., 2017; Mehta, et al., 2018) Zika has an incubation period of 3-14 days and symptoms typically last 2-7 days. (Grossi-Soyster, et al., 2017; WHO, 2018b) The main concern with maternal ZIKV infections, regardless of if symptomatic or not, is microcephaly and other congenital malformations (congenital Zika syndrome[CZS]) in infants as well as the possibility of preterm birth, miscarriage, and intra-uterine growth restriction. (Krow-Lucal, et al., 2018; Weaver, et al., 2018; WHO, 2018b) CZS includes other malformations such as eye and vision abnormalities, hearing loss, learning disabilities, epilepsy, and cerebral palsy. There is greater fetal susceptibility to CZS for infections occurring in the first trimester. (Satterfield-Nash, et al., 2017; Weaver, et al., 2018; WHO, 2018a, 2018b) Microcephaly is a smaller head size than normal due to abnormal brain development or loss of brain tissue, which leads to varying child outcomes according to the extent of brain damage. (WHO, 2018b) Some infants with microcephaly develop normally and some infants without microcephaly develop congenital Zika syndrome. (WHO, 2018a) The risk of congenital malformations is estimated at 5 -30% of infants born to women with symptomatic and asymptomatic ZIKV infection during pregnancy compared to the normal rate of microcephaly being about one in a thousand infants. (Krow-Lucal, et al., 2018; Weaver, et al., 2018; WHO, 2018a, 2018b) Adults can also have long-term neural effects due to ZIKV infections, including learning and memory impairment. (Weaver, et al., 2018)

Another concern for adults and children is the development of GBS, neuropathy, and myelitis, although those with Zika-induced GBS typically fully recover. (Weaver, et al., 2016, 2018; WHO, 2018b) GBS can occur due to direct ZIKV infection thus having a short period of time between rash and GBS or GBS can occur due to autoimmune cross-reactive antibodies thus occurring later after the infection. (Weaver, et al., 2018) Currently, there is only supportive treatment, thus the importance of ruling out dengue before giving NSIADs for joint pain. (Simon, et al., 2015) For microcephalic infants, early intervention with stimulation may positively impact development and there is a need for family counseling and support. (WHO, 2018a) To conclusively determine if there is lifelong protective immunity, researchers will need to collect data from endemic countries. (Kindhauser, et al., 2016) Based on the lack of microcephaly and GBS seen in endemic areas, it is possible that once infected with Zika, there is protective immunity. (Weaver, et al., 2016)

1.4 Vaccines

Vaccines are currently being researched, developed, and tested in preclinical and clinical trials. Until there are safe and approved arboviral vaccines for use in the Caribbean, the current best prevention methods involve vector control (outlined below). (WHO, 2018b)

It is important to have clearly defined clinical endpoints for determining efficacy due to the concern for dengue and zika vaccines for the potential for ADE. There is not enough evidence to yet determine if antibody cross-reaction in *Flaviviruses* can cause ADE between dengue and Zika. (Barouch, et al., 2017; Dejnirattisai, et al., 2016) Specifically for Zika it will be important to determine efficacy and effectiveness based on CZS and GBS prevention as well as determining safe immunization scheduling for women who are or plan to be pregnant.

Recently, the National Institutes of Health (NIH) published results from a phase I trial using a mosquito saliva peptide-based vaccine. The premise was based on previous research indicating mosquito saliva has immune modulating proteins. (Pingen, et al., 2016; Vogt, et al., 2018) Eligible participants were inoculated with two doses and then later exposed to feeding by uninfected *Aedes aegypti* mosquitoes. The vaccine contained four synthetic salivary peptides from *Anopheles gambiae* mosquitoes. After the mosquito feeding, the site was evaluated for redness and swelling. There was some mild to moderate vaccine-related adverse events at the injection site and seem more in the adjuvant group than the non-adjuvant and control groups. One adjuvant participant developed an erythema after the first injection. After feeding, the mosquitoes were evaluated for any changes in the life span and progeny survival over the life span (eggs, larvae, pupae, and adults) of which there was no difference among vaccine groups. Outcomes were promising, the vaccine was considered safe and for the adjuvant group there was a significant increase in vaccine-specific antibodies, but all groups had the same antibody levels by the end of the study, about one year. The vaccine was proven to be tolerated and immunogenic when adjuvanted, thus a viable option for a vector-targeted vaccine. (Manning, et al., 2020) There is more research needed to understand the human immune response to mosquito saliva as well as if truly protective against each mosquito-borne pathogen. Additionally, there needs to be an evaluation of if the vaccines need to be specific to mosquito genus or if there is cross-protection. If successful in further clinical trials, this vaccine would eliminate the need for pathogen specific vaccines.

1.4.1 Dengue vaccines

In 2015, Sanofi Pasteur's recombinant tetravalent dengue vaccine with a yellow fever backbone (CYD-TDV), Dengvaxia, was licensed for use in a few endemic countries. Of which non are Caribbean countries, but the European and U.S. territories can use the vaccine due to licensing approval in the United States and in Europe. (FDA, 2019; Sanofi, 2017, 2019) This vaccine replaced the RNA for the pre-membrane (PrM) and envelope (E) protein from the yellow fever virus vaccine (YF17D) with the corresponding RNA from the four dengue serotypes. (Guy, et al., 2010) Data from the vaccine's clinical trials, phase III/IV, indicated those over nine years old had greater efficacy, with vaccine immunity lasting four years. (Guy, et al., 2017; Hadinegoro, et al., 2015) Yet an individual's age, serostatus, and serotype affected vaccine effectiveness and those in the placebo group had higher hospitalization rates three years post inoculation. (Guy, et al., 2017; Sridhar, et al., 2018) More clinical trials showed the vaccine was ineffective against the DENV-2 serotype with re-immunization more effective than first-time. (Capeding, et al., 2014; Hadinegoro, et al., 2015; Sabchareon, et al., 2012)

Due to this information, the WHO made safety recommendations for determining who should receive the vaccine via either pre-vaccination screening of individuals, the preferred method, or by using recent high resolution documentation of seroprevalence rates of over 80% by age 9 years old. This is to ensure those vaccinated have previously been exposed to dengue naturally in order to reduce the risk of developing severe dengue. Thus, the vaccine is safe and effective for those aged 9 to 45 years who live in dengue endemic areas and have a documented exposure to dengue. In higher dengue transmission countries the acceptable age for vaccination may be lowered and for lower dengue transmission countries the lower limit of acceptable age may be higher. (WHO, 2019e) Recently, the United States Food and Drug Administration (FDA) has approved the vaccine of those aged 9 to 16 years, live in endemic areas, and have a laboratory confirmed previous dengue infection. (FDA, 2020)

Which method to use for Dengvaxia vaccine implementation involves evaluating the balance between population level benefits versus individual risk. To determine the optimal age range for each country involves knowing at what age is severe dengue incidence the highest by using routine hospital laboratory-confirmed surveillance data. Thus the great importance of strong surveillance systems and highly specific and sensitive biological tests, such as plaque reduction neutralization test (PRNT), IgG antibody detection, or other laboratory confirmed methods used for diagnosis and screening. Further, the vaccine should not be considered a tool for outbreak response. (Ariën, et al., 2018; CDC, 2017b; WHO, 2019a, 2019e) Even if vaccination becomes universally available, it will be important to continue with integrated vector management (IVM), described below. Additionally, regardless of vaccination status, those with dengue symptoms should seek medical care. Also, those vaccinated should be observed long-term to ensure the absence of developing severe dengue disease. (Guzman, et al., 2010)

A live, attenuated tetravalent dengue vaccine candidate uses DENV-2 as the backbone, including the NS-1 or non-structural genome, and incorporates the PrM and E protein RNA from DENV-1, 3, and 4, also called TDV or DENVax. This vaccine, developed by Takeda, proved safe and efficacious in both phase I trials, testing doses and administration routes, although one participant had mild dengue-like symptoms. (Osorio, et al., 2014; George, et al., 2015) Phase II trials enrolled adults and children. There were no serious adverse events in both baseline seropositive and seronegative participants. (Sirivichayakul, et al., 2016) This vaccine is currently in phase III trials. There are other phase I and II trials occurring that are testing dosing regimen, including testing a booster dose. (Osorio, et al., 2015)

A monovalent vaccine rDENxΔ30, where x is the different serotypes, and its derivatives are either no longer being pursued or are used as a research tool to develop components to be used in a quadrivalent live, attenuated vaccine. This vaccine and its components, including TV003/TV005, were developed by NIAID. (WHO, n.d. c) The TV003/TV005 vaccine is a mixture of four attenuated recombinant derivatives from the rDENxΔ30 research vaccine. The TV003/TV005 vaccine had more resistance to DENV-2 than Dengvaxia and thus produced more balanced immune responses. Clinical trial participants reported a mild rash and there was protection from all serotypes. Yet, more participants produced protective antibodies to TV005, which contains more DENV-2 components, than TV003. (Kirkpatrick, et al., 2015, 2016)

Other dengue vaccine types include live attenuated, inactivated whole cell, recombinant subunit, and DNA candidates and are summarized by Deng, et al. (2020) but will be briefly mentioned here. Developed by WRAID, the tetravalent live, attenuated vaccines, PIV and LAV, used structural protein components. There was promising results in animal studies and there is now recruitment for phase I trials. (Deng, et al., 2020; Simmons, et al., 2010) The recombinant subunit vaccine, DEN1-80E, uses a recombinant truncated E protein. From phase I trials, the vaccine proved safe and efficacious, but without long-lived immunity. (Manoff, et al., 2015) Lastly, the DNA vaccine, developed by the US Naval Medical Research Center, started as a monovalent plasmid containing PrM and E proteins from DENV-1, but later became tetravalent by combining the remaining three serotypes' monovalent vaccines. In phase I trials, there was low levels of protective immunity developed and so further research is evaluating using an adjuvant. (Beckett, et al., 2010; Porter, et al., 2012)

1.4.2 Chikungunya vaccines

Chikungunya vaccine development has a long history starting in the 1960s. The early efforts involved inactivated African strains, yet they never progressed further than testing in mice and monkeys. (Kitaoka, 1967; Powers, 2017) The next vaccine developed was a live, attenuated vaccine candidate by Walter Reed Army Institute of Research (WRAID). It was tested in both monkeys and mice with promising results. (Harrison, et al., 1967) This vaccine completed phase I and II trials before funding as well as the unpredictable chikungunya epidemiology ended the vaccine trial in 1998. (McClain, et al., 1998, Edelman, et al., 2000; Hoke, et al., 2012) The phase I and II trial results were promising yet some participants experienced arthralgia, a concern given this is a common symptom of infection. (McClain, et al., 1998, Edelman, et al., 2000) The investigational new drug (IND) protocol for the live, attenuated vaccine was left open until 2011 for continued research result submissions. Interestingly, after the 2006 chikungunya outbreak in La Reunion, this vaccine was requested for additional research purposes by France's Ministry of Health. (Hoke, et al., 2012; Powers, 2017)

Other chikungunya vaccines were developed after the reemergence and expansion across the globe. One promising vaccine in development uses virus-like particles (VLP); these structurally look like the CHIKV but it does not contain nucleic acid, and so it is replication incompetent. Researchers started with a West African and Central/East African strain and discovered there was increased production West African VLP's from their cell culture. They justified continuing with this strain as there is high similarity of amino acids among CHIKV strains along with cross-reactive serology thus a vaccine using one strain would be cross protective. (Akahata, et al., 2010; Goo, et al., 2016; Powers, et al., 2000) The VLP vaccine was tested in mice and monkeys with promising results leading to phase I clinical trials and now phase II trials.

(Akahata, et al., 2010; Chang, et al., 2014; Powers, 2017; Weaver, et al., 2018) The vaccine produced neutralizing antibodies without negative side effects, yet there was a waning of the antibody titer over time. (Chang, et al., 2014; Powers, 2017)

The other promising CHIKV vaccine is the recombinant, live attenuated measles vaccine with CHIKV structural protein genes which then produces a chikungunya VLP. The vaccine has been previously used for developing immunity against *Flaviviruses* in mice and monkeys. (Desprès, et al., 2005; Brandler, et al., 2010) This vaccine proved promising in animal studies, but during phase I clinical trials there was dose dependent level of protective antibodies developed as well as dose dependent severe adverse events such as headaches, musculoskeletal pain, and flu-like illness. (Brandler, et al., 2013; Ramsauer, et al., 2015) But importantly, there were no developments of arthralgia. (Ramsauer, et al., 2015) The vaccine is now in phase II clinical trials.

Some other vaccines being developed include subunits, live attenuated, DNA, and recombinant. None of the other vaccines have gone past the preclinical trials. The article by Powers (2017) has a summary of all the current CHIKV vaccines in development. Important for all the safety evaluations during clinical trials is the absence of participants developing GBS and arthralgia.

1.4.3 Zika vaccines

Zika vaccine development is much newer, initiated due to its New World outbreak. (Weaver, et al., 2018) There are numerous vaccine candidates in phase I and two are starting phase II trials. There are different methods employed such as DNA, inactivated whole cell, mRNA, and recombinant vaccines being tested. (WHO, n.d. c) In preclinical trials, all vaccine candidates developed neutralizing antibodies in mice as summarized by Abbink, et al. (2017)

There are a couple DNA vaccines, of which one is recruiting for Phase II trials. (WHO, n.d. c) The DNA vaccines have expressed ZIKV precursor membrane and envelope proteins and the National Institute of Allergy and Infectious Diseases (NIAID) has added Japanese encephalitis virus envelope stem and for another vaccine they used wild-type ZIKV, currently in phase II trials in the Americas and Caribbean. (Tebas, et al., 2017; Gaudinski, et al., 2018) Tested in these phase I trials were dosing, immunization schedules, and administration routes of which there was dose-dependent antibody responses. Importantly, the vaccines were well tolerated with only mild to moderate vaccine-associated adverse reactions.

WRAID has completed phase I trials for three purified, inactivated vaccines. Tested was one dose regimen and administration route. There was mild to moderate vaccine related adverse effects with neutralizing antibodies produced. They intend to perform follow-up analysis on dosing and immunization schedules. (Modjarrad, , et al., 2018)

The other vaccine type that is in phase I/II trials is mRNA based, developed by Moderna Therapeutics. Preclinically, this vaccine and a live-attenuated vaccine were also tested in immunocompromised pregnancy mice models. Both vaccines prevented fetal death, yet ZIKV RNA was found in various tissues in the mice including the placenta and fetal heads. (Richner, et al., 2017) It would be important to study the effects in immunocompetent mice to determine if viral replication will also occur.

As with all of the vaccines that continue to phase III/IV, it will be important to determine what is considered an adverse event, such as CZS, and thus it will be important how vaccine efficacy will be defined. Additionally, it will be important to ensure safety in all phases of clinical trials with the absence of participants developing GBS. Further, it will also be important to determine immunization scheduling for pregnant or planning to be pregnant women. The mRNA vaccine would be safer for women of childbearing age due to its lack of viral replication. Whereas the live, attenuated vaccine may produce longer-term protection and be used for males and females prior to sexual debut but would require adequate time between vaccination and pregnancy. (Barouch, et al., 2017; Richner, et al., 2017) It also will be difficult to accomplish phase III trials due to the reduction in Zika transmissions globally and there is ethical concerns regarding challenging in clinical trials. (Abbink, et al., 2017; NIH, 2017) One way around this is following the FDA's Animal Efficacy Rule by showing strong correlation of protection, ZIKV neutralizing antibody titers, in preclinical models that translate to humans when it is unethical to test efficacy in humans. (FDA, 2015) Another study design for determining vaccine efficacy is ring vaccination as used during the Ebola vaccination trials. (Henao-Restrepo, et al., 2015) If clinical trials continue, instead of using the FDA's Animal Efficacy Rule, there will need to be large trials to accomplish enough statistical power due to the rare rates of microcephaly. Moreover, there is also the approach of receiving regulatory approval by using clinical endpoints that do not contain CZS. (Barouch, et al., 2017)

1.5 Commonalities of Arboviral Diseases

Dengue, chikungunya, and Zika infections all have common symptomatology leading to a greater difficulty in differential diagnosis. Further, these viruses are spread by the same mosquitoes and so have a common geographical distribution. (Paupy, et al., 2009; Waggoner, et al., 2016; Weaver, et al., 2018; CDC, 2017c) As such, a differential diagnosis is important as the supportive therapy can be different, specifically to not use NSAIDs with a dengue infection. (Simon, et al., 2015) But differential diagnosis requires biological methods and can be difficult as antibodies to

Flaviviruses all cross-react. This cross-reaction can be further complicated by vaccination to other *Flaviviruses* such as yellow fever and Japanese encephalitis leading to a false-positive result. (Felix, et al., 2017) Thus the need for more specific diagnostic methods such as multiplex RT-PCR to detect mono-infections and co-infections, PRNT, IgG enzyme-linked immunosorbent assay (ELISA), as well as other specific biomarkers of infection. (Ariën, et al., 2018; CDC, 2017c; Guzman, et al., 2010; Kindhauser, et al., 2016; Waggoner, et al., 2016;) Additionally, dengue diagnosis tests have different sensitivity dependent on illness duration. (Simmons, et al., 2012) Chikungunya, being an *Alphavirus*, does not have cross-reactive antibodies to *Flaviviruses*. (Kam, et al., 2015) Further complications include the lack of specific treatments available as there is only the option of supportive therapy, including for GBS, microcephaly, and severe dengue. (Guzman, et al., 2010; Simon, et al., 2015; Weaver, et al., 2018) There is research into specific treatments including anti-CHIKV antibodies given to exposed neonates to prevent vertical transmission during intrapartum, evaluating drugs to prevent *Flavivirus* replication, such as ivermectin which is in a phase II/III trial, and antibiotics that prevent ZIKV replication and the negative side effects ZIKV has on neural cells. (Barrows, et al., 2016; Couderc, et al., 2009; Mastrangelo, et al., 2012; Retallack, et al., 2016)

Due to the common vector, mosquitoes, it is important to prevent further spread by protecting patients from being bitten by mosquitoes in the first week of illness. (Simon, et al., 2015; PAHO, 2016a) The use of bed nets or screens on windows and doors, use of bugspray, and wearing long sleeves and pants can help prevent the spread of infection from sick individuals. (Paupy, et al., 2009; Simon, et al., 2015; PAHO, 2016a; WHO, 2019a) Additionally, due to the potential for severe symptoms with arboviral diseases, it is recommended by the WHO and the

CDC to seek care at a healthcare facility where supportive therapy can lessen disease severity and drastically reduce the chance of death to severe dengue. (CDC, 2017b; PAHO, n.d. e)

1.5.1 Arboviral Diseases' Impact on Populations

According to the WHO, dengue's numerous serotypes and endemo-epidemic pattern of outbreaks has an alarming impact on human health, as well as the national and global economies. (WHO, 2019a) The chikungunya outbreak is estimated to have cost Venezuelans over 1 billion dollars in lost wages. (Yactayo, et al., 2016) For comparison, in 2018 Venezuela had 295 cases and the Eastern Caribbean Countries (ECC) region had 144 cases and in 2019 Venezuela has reported 52 cases and ECC reported 27 cases. (PAHO, n.d. f) After the ZIKV outbreak in Brazil, CZS has had negative socioeconomic consequences for affected families as the mothers take off time from work to devote more time caring for their children. (Weaver, et al., 2016) While malaria is not a concern for the ECC region and not a large concern for the Caribbean it can be an example of economically what is at risk in mosquito-borne disease high-transmission rate areas. Africa is a malaria high-transmission rate area and it has been estimated that a 1.3% reduction in Gross Domestic Product (GDP) is attributed to malaria. This annual loss is compounded over the years with noticeable differences in GDP between countries with and without malaria. Furthermore, in high malaria burden countries malaria accounts for up to 40% of public health expenditures, between 30% to 50% of the inpatient hospital admissions, and up to 60% of outpatient health clinic visits. Moreover, malaria disproportionately affects those who are poor and cannot afford treatment and/or have limited access to health care. Clearly, malaria infections trap families and communities in poverty. (PAHO, n.d. h)

Another impact arboviral diseases have on communities is reduced tourism. The CDC issued travel warnings during the Zika outbreak and other outbreaks as well, including the Jamaica dengue outbreak in early 2019. (CDC, 2019b) In 2019, tourism accounted for 15.5% of the total economy and 2.4 million jobs in the Caribbean. (World Travel and Tourism Council, 2019) For countries where the economy relies on tourism, an outbreak not only hurts those directly affected by the disease, but everyone via the country's economy and individual's livelihoods.

The great direct and indirect harm caused by arboviral diseases indicates the importance of protecting oneself and the community from arboviral infections. The best method is vaccination, yet with none licensed, or for Dengavaxia not currently in use, the next best option is vector control and preventing those who are sick from getting bitten by mosquitoes.

1.6 Information on *Aedes* mosquitoes

Aedes mosquitoes are an anthropophilic vector where female *Aedes* mosquitoes typically bite multiple people each feeding period. (Scott, et al., 2000; WHO, 2019a; Klitting, et al., 2018; Paupy, et al., 2009) *Ae. albopictus* is an opportunistic zoophilic feeder, but prefers humans when in urban settings, thus an important concern for zoonotic diseases and sylvatic transmissions. (Delatte, et al., 2010; Paupy, et al., 2009; Scott, et al., 2000) *Aedes* mosquitoes usually bite during the day and are exophagic, preferential feeding during the early morning and late evening and both indoors and outdoors near buildings. (Paupy, et al., 2009; CDC, 2017a; WHO, n.d. a) Additionally, *Aedes* mosquitoes prefer to lay their eggs indoors and in domestic water sources such as discarded water bottles and flowerpots above the waterline. Whereas *Ae. albopictus* is more likely to lay eggs in more natural items in peri-urban areas and shady parks such as coconut husks, bamboo stumps, and discarded tires as well as in natural water habitats with plants. (ECDC, 2016a, 2016b; PAHO, n.d. e; WHO, n.d. a; Hawley, 1988; Klitting, et al., 2018; Paupy, et al., 2009; Ngoagouni, et al., 2015; Powell, et al., 2013) Importantly, *Aedes* mosquito eggs attach to the containers where they are deposited and can survive desiccation for over a year. (Powell, et al., 2013; PAHO, 2016a; ECDC, 2016b, WHO, 2019a) The domestic form of *Aedes* mosquitoes is often found within 100 meters of human habitats and regardless of if they are the domestic form or not, they have a flight range of 25 to 400 meters. (ECDC, 2016a; PAHO, 2016a) Being adapted to the urban environment, *Aedes* mosquitoes do not rely on rainfall for breeding sites. (ECDC, 2016a; Klitting, et al., 2018, Paupy, et al., 2009) Interestingly, both *Aedes* species are capable of coexistence in larval and adult habitats and they can coexist with other mosquito genus'. As such, it cannot be assumed that one species will displace the other even with *Ae. albopictus* demonstrating in field studies to have a higher population growth rate. (Juliano, et al., 2004; Paupy, et al., 2009; Ngoagouni, et al., 2015)

Aedes aegypti are confined to the tropics and subtropics region of the world, where as *Aedes albopictus* can also live in temperate and cold temperate regions. (Paupy, et al., 2009; Simmons, et al., 2012; WHO, n.d. a) Interestingly, *Ae. albopictus* is highly adaptive due to their tolerances to low temperature (about 9 °C/ 48 °F), ability to hibernate, and the ability to shelter in microhabitats which allows for the spread to colder temperate regions. (Paupy, et al., 2009; WHO, 2019a) Further, *Ae. albopictus* eggs can suspend development (diapause) overwinter (as long as it is less than six months) with temperate mosquitoes' eggs survive temperatures as low as -10°C/14 °F and tropical mosquitoes' eggs survive temperatures as low as -2 °C/ 28 °F. (Paupy, et al., 2009; ECDC, 2016b) In shared larval water sources, *Ae. aegypti* are dominant in early rainy season and *Ae. albopictus* comprise the majority of larvae in late rainy season. (Ngoagouni, et al., 2015; Powell, et al., 2013) Most mosquito-borne disease outbreaks occur during and soon after the rainy season as well as at the end of the dry season, although having water containers in and near homes can contribute to longer outbreaks that do not end in the dry season. (CDC, 2017a; WHO, n.d. a) All these attributes, specifically the anthropophilic and endophilic preferences, indicate urban areas are typically more at risk of outbreaks than rural.

2.0 Epidemiology

The Caribbean Mosquito Awareness Week targets the participation of all the Caribbean islands. However, the epidemiological data for dengue, chikungunya, and Zika as well as the Mosquito Awareness Week 2019 Activities in this report will focus on the countries under the PAHO Barbados and ECC office excluding the French Department of the Americas (i.e., French Guiana, Guadeloupe, and Martinique). The French Department of the Americas (FD) is excluded due to the language barrier and according to PAHO's Barbados and the ECC office's Advisor for Climate Change and Environmental Determinants of Health, who oversees MAW implementation and evaluation, it is difficult to coordinate with these countries due to the fact that overseas territories are still under the governance of their mainland country, in this case France. The included countries in this evaluation are: Anguilla, Antigua and Barbuda, Barbados, British Virgin Islands, the Commonwealth of Dominica, Grenada, Montserrat, Saint Kitts and Nevis, Saint Lucia, and Saint Vincent and the Grenadines.

The epidemiological data for the number of cases of dengue, chikungunya, and Zika came from PAHO's Health Information Platform for the Americas (PLISA) database accessed on July 16, 2019, as such the epidemiological (epi) week reported in 2019 will be listed in this report. The data in PLISA is reported by the country's Health Ministries to PAHO. (PAHO, n.d. f) The chikungunya data for 2015 - 2017 was not listed in PLISA, but came from PAHO's Chikungunya: Data, Maps, and statistics website. (PAHO, n.d. d) All data represented in the figures is the total number of cases, i.e., suspected, confirmed, and imported.

In 2001, PAHO's 43rd Directing Council developed a framework for dengue prevention and control, discussed below. Outlined in this document was recommendations for what to include in dengue case reporting (probable cases, laboratory-confirmed cases, serotypes, deaths, etc.). Additionally outlined is the frequency of reporting the data weekly to PAHO, from Ministries of Health (MoH), so that PAHO can give the data monthly to the member states. Standardizing the necessary information as well as regularly communicating and disseminating the information allows for a timelier reaction to any outbreaks for all countries in the Americas region. (PAHO, 2001) In 2016, PAHO's 55th Directing Council developed a framework for arboviral prevention and control that included strengthening surveillance for Zika and chikungunya. In the resolution document, there was no mention of what information to report nor the frequency. (PAHO, 2016d) This may explain the low number of reporting countries regarding confirmed cases and deaths attributed to chikungunya and Zika compared to dengue.

Figure 2 shows the reported dengue cases in Barbados and the ECC excluding FD for 2014 - 2019. For 2019, there was a range of epi week 6 - 24 being reported and all countries reported data for 2019. There was one reported death in Barbados in 2015 and since then there have been zero reported deaths from all in the Barbados and ECC region, although Anguilla did not submit a report for deaths in 2017. The case fatality rate for the reported deaths is less than 1% which is in line with the WHO's assessment of what proper case management can accomplish. Numerous countries saw a spike in dengue cases in 2016. This may be due to the Zika outbreak as it was originally difficult to differentiate the two viruses and so some cases may actually be Zika. Another possibility is a concomitant dengue outbreak with Zika or even an increased number of patients seeking medical care due to the Zika outbreak. The last possible explanation is an increase in cases due to lax VC operations contributing to increased mosquito populations. Antigua and Barbuda saw a spike in cases in 2019, when most other countries were seeing a decline or similar numbers to previous years. Data on dengue cases is more complete than for Zika and chikungunya thus trends seen for dengue cases are more likely to be accurate.

Figure 3 shows the dengue and severe dengue cases for the select Barbados and the ECC countries reporting severe dengue cases for 2014 - 2019. Barbados and Dominica have reported severe dengue cases during the 2014 - 2019 period. Although, zero cases of severe dengue have been reported from all Barbados and ECC countries since 2016. The maximum reported number of severe dengue cases was in Barbados in 2014 (2 cases). There was less than 1% of dengue cases developing severe dengue.

Figure 4 shows the reported chikungunya cases in Barbados and the ECC excluding FD for 2014 - 2019. Epi week 15 was the last reported week for 2019. There were no reported chikungunya deaths and very few imported cases from the countries that did report data. The imported cases were reported in Anguilla (2 cases in 2014) and Barbados (8 cases in 2014). No country reported 2017 data regarding chikungunya cases. Saint Kitts and Nevis (2 cases) and Saint Lucia (2 cases) were the only reporting countries in 2018. In 2019, Barbados (27 cases) and Saint Lucia (0 cases) were the only reporting countries. Regarding Barbados not reporting CHIKV cases in 2018 and reporting 27 cases in 2019 does not indicate a trend showing VC operations failed for the year. Moreover, with the Zika outbreak in 2015 - 2016, it is possible that the reports for chikungunya decreased due to the greater concern for the higher morbidity attributed to Zika and thus a re-focus of limited resources.

Of the countries that reported, there were no imported cases or deaths attributed to Zika in 2015 - 2019 in Barbados and the ECC. Figure 5 shows the reported Zika cases in Barbados and the ECC excluding FD for 2015 - 2019. Epi week 12 was the last reported week for 2019 with zero cases reported for the few countries submitting data. In 2016, every country reported Zika cases.

Again, it appears there were zero cases reported for numerous countries in 2017 - 2019, yet many countries did not report any data. Even with a spike in Zika cases in 2016 followed by the lack of cases from 2017 onwards, this does not necessarily indicate VC operations are truly successful. Interestingly, in 2016 with the Zika outbreak in the Caribbean, there was also some spikes in cases reported for chikungunya and dengue.

The CDC (2018) mentioned, "… 'epidemiologic silence' does not mean absence of risk, travelers should not go into endemic areas without taking protective measures." The lack of chikungunya and Zika cases reported by numerous countries makes it appear as if there were zero cases, this is likely not the case as the lack of a report does not equate to zero cases reported. Failure to report cases may be intentional as there is no requirement to submit data to PAHO. Countries may fear losing tourists if there is a perceived health threat, so by not reporting cases it artificially looks safer to visit the countries. Therefore for the PLISA data, there is concern that a lack of report does not mean the Ministries of Health in those countries are finding zero cases. Further, the lack of reports or reporting zero cases should not mean for those living in those countries that it is safe to stop all VC efforts nor is it indicative of vector control program effectiveness.

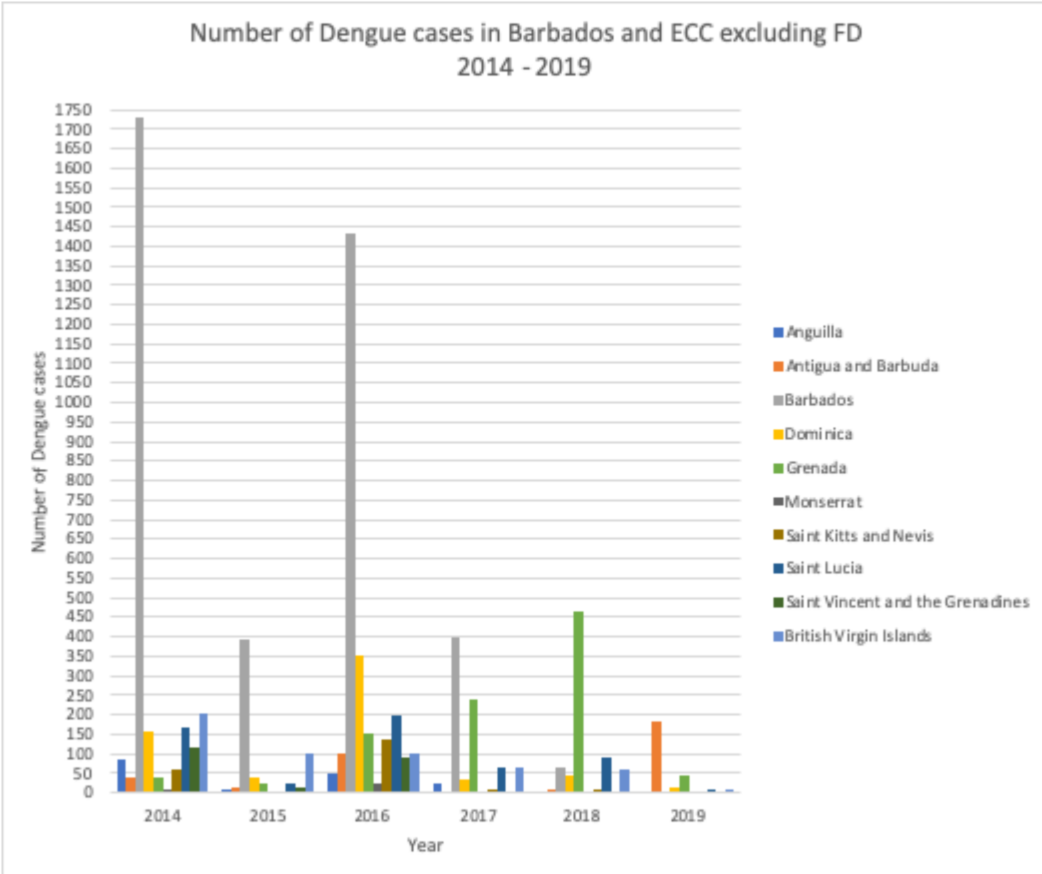

Figure 2 The number of all dengue cases in Barbados and ECC excluding the French Department of the Americas (Guadeloupe, French Guiana, and Martinique) for the years reported, 2014 - 2019.

Data source: PAHO's PLISA

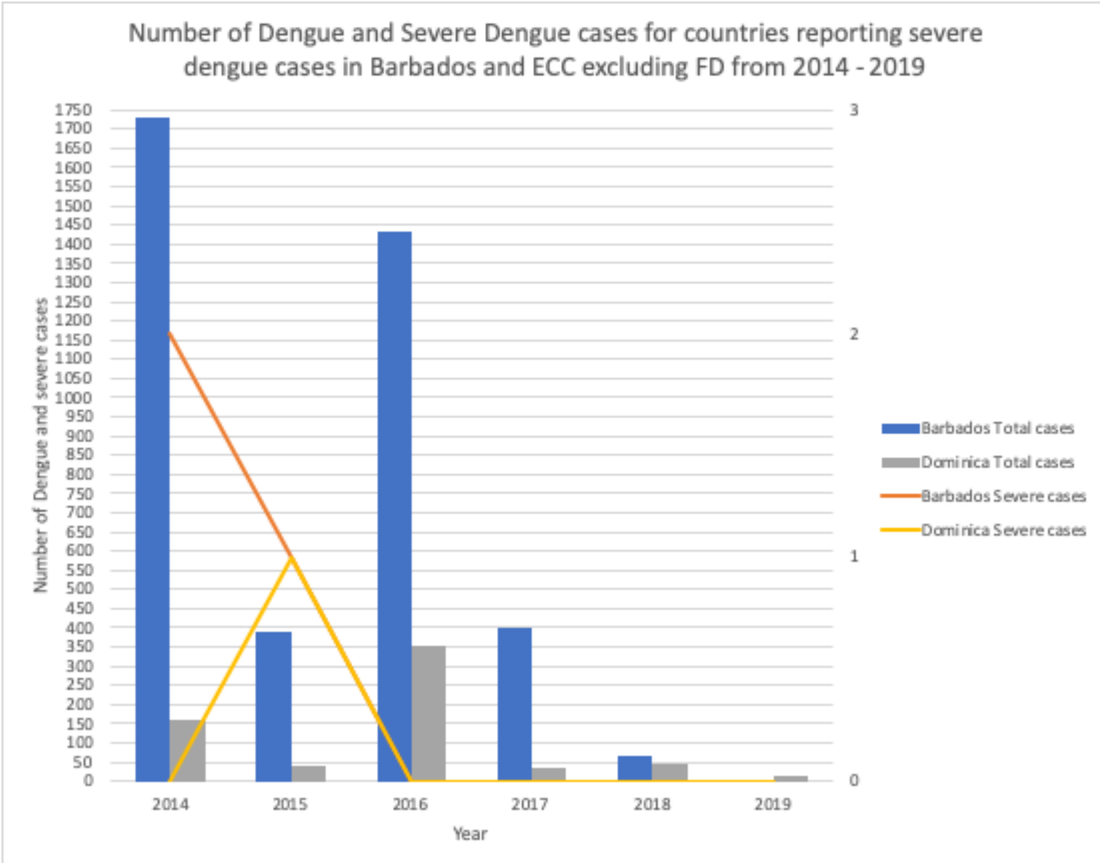

Figure 3 The number of all dengue cases and severe dengue cases in Barbados and ECC excluding the French Department of the Americas (Guadeloupe, French Guiana, and Martinique) for the countries reporting and for the years reported, 2014 - 2019.

Data source: PAHO's PLISA

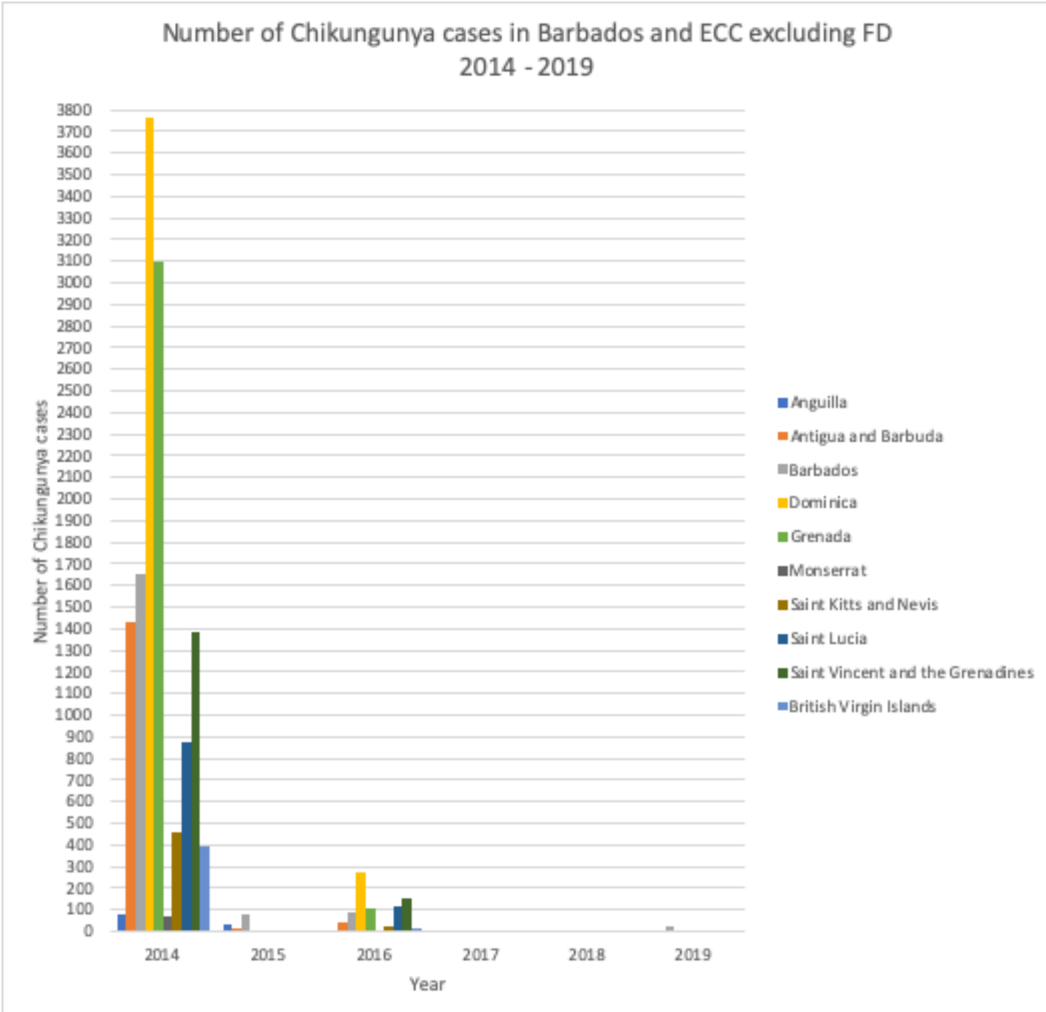

Figure 4 The number of chikungunya cases in Barbados and ECC excluding the French Department of the Americas (Guadeloupe, French Guiana, and Martinique) for the years reported, 2014 - 2019.

Data source: PAHO's PLISA and Chikungunya: Data, Maps, and statistics

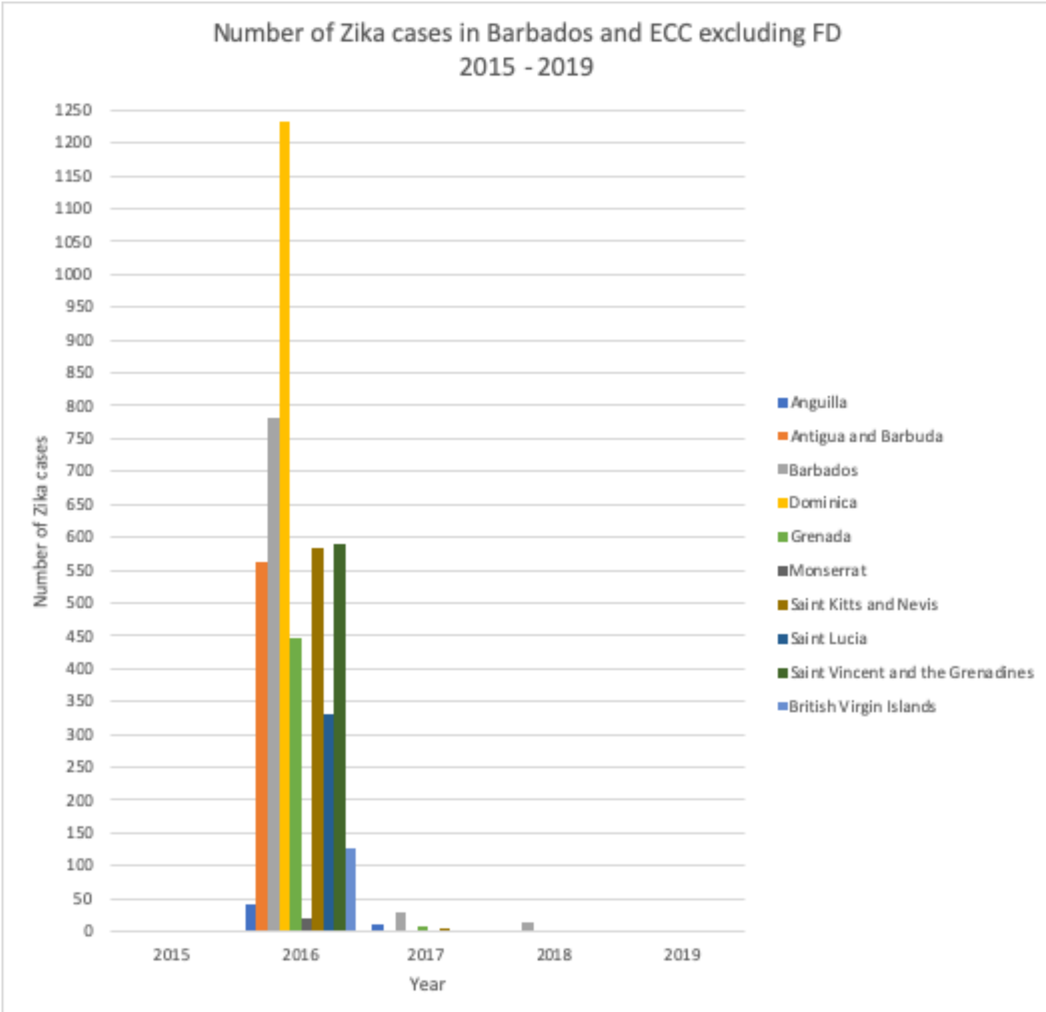

Figure 5 The number of Zika cases in Barbados and ECC excluding the French Department of the Americas (Guadeloupe, French Guiana, and Martinique) for the years reported, 2015 - 2019.

Data source: PAHO's PLISA

3.0 PAHO and WHO's Strategies for Prevention and Control of Arboviruses

Strategies for mosquito control have changed throughout the last century. As previously mentioned, there was a mostly successful mosquito elimination campaign, primarily using insecticides, in the early to mid 20th century. This fell apart as it became more successful mostly due to lack of continued political will and financial resources, mosquito resistance to insecticides used, increased international travel, and insufficient environmental sanitation facilitating the re-introduction and spread of *A. aegypti*. Further, the lack of a strong surveillance system hid the emergence of *A. albopictus* and thus the ability to institute timely control measures. (Brathwaite, et al., 2012; Webb, 2016) Moreover, any new strategies must learn from and adapt previous elimination efforts while incorporating new technology and engaging the public as populations are larger combined with a larger volume of global trade (including used tires) than that of the mid-20th century contribute to further increased susceptible population and global spread. (Paupy, et al., 2009; Webb, 2016) In 2001, most dengue control programs were vertical, requiring a strong sustained political will with economic commitment and typically with the focus being on using adulticides and eliminated breeding sites. (Paupy, et al., 2009) PAHO aimed to promote a new strategic framework to have some continuity in programs developed by each country while keeping their specific needs in mind and allowing for their specific social, economic, political, historical, and cultural contexts. Included in the framework was to strengthen dengue prevention and control in national programs through improved surveillance, community participation, and social communication and advocacy. The developed programs from this framework were to rely on concomitant actions from intersectoral partnerships for sustainable environmental planning, urban planning, improved access to water and sanitation, and health education. To accomplish this by using a diagonal approach with the local government acting as an active leader of the programs with individual households, communities, non-governmental organizations (NGOs), educational sectors, environmental sectors, private industry, and the healthcare sector participating. The local government would implement health education, legislation, solid waste disposal, and water supply and disposal (so homes and businesses can eliminate the need for rainwater collection). (Brathwaite, et al., 2012; PAHO, 2001) Using a diagonal approach ensures VC programs optimize their limited financial and human resources. (PAHO, 2016d) Additionally, the desire was to move into actions for prevention as opposed to reactionary due to an outbreak. Programs that wait for an outbreak before taking action can soon find each outbreak escalating due to the increased vector prevalence and increased dengue serotype circulation. Moreover, to save adulticides for during outbreaks due to its ephemeral effect. To accomplish this strategy, PAHO developed a standardized dengue data reporting and dissemination procedure, previously mentioned in the Epidemiology Data section. In the strategy some preventative methods mentioned are using larvicides and source reduction (the most effective method for reducing mosquito density) and that both require maintenance and can be time-consuming. (PAHO, 2001) Source reduction is something that everyone in the community can participate in, schools, churches, local industries, residents, and so on. (Paupy, et al., 2009; PAHO, 2001, 2016a) The activities taken for VC should be nation-wide as mosquitoes and social determinants of health do not adhere to borders, thus the need for collaboration among different sectors and effective communication between neighboring countries.

The 2001 PAHO framework along with the increasing dengue incidence, became the backbone for future strategic framework. This includes the 2003's *Integrated Management Strategy for Dengue Prevention and Control (IMS-Dengue)* that focused recommendations on intersectoral participation and action for integrated vector management (IVM), epidemiology, entomology, healthcare, laboratories, the environment, and social communication with clear definitions and responsibilities within the scope of expertise for strengthening national programs. Also included was for countries to develop strategies for responding to outbreaks. (Brathwaite, et al., 2012; PAHO, n.d. g)

Integrated vector management is an important part of vector control. IVM involves multi-sectoral/intersectoral approach using multiple efficacious, ecologically sound, and sustainable resources for vector control as history has proven one method is not sufficient for mosquito control due to the selective pressures it creates. (ECDC, 2016a; WHO, n.d. b) Included in IVM is the use of advocacy, social mobilization, intersectoral collaboration, use of chemical and biological VC methods for the adult and immature or aquatic (egg, larva, and pupae) stages, operational entomological and epidemiological surveillance, and training and capacity building in the community and in the various levels of government. (WHO, n.d. b) It is easy to see that since 2001, IVM has been integral in all the framework PAHO has introduced.

Soon after the chikungunya outbreak and during the Zika outbreak in the Americas, and further building on previous strategic frameworks developed (mentioned above), PAHO developed the *Strategy for Arboviral Disease Prevention and Control (IMS-Arbovirus)* in 2016 as each arbovirus cannot be viewed as an independent problem. Again the focus for the strategy's framework was on intersectoral collaboration on comprehensive surveillance, laboratory diagnosis, patient care, and IVM emphasizing social participation. Accomplished through environmental management, surveillance, encouraging political will and financial commitment, strengthening the health sector capacity in differential diagnosis (along with laboratories), arboviral disease management, and communication with the community. Importantly, there was the inclusion of ensuring the most vulnerable in the population are protected, involving and empowering the community to actively participate in VC, and using the WHO's vector control advisory group to help pilot testing new VC tools, e.g. sterilized male mosquitoes, *Wolbachia* infected mosquitoes, and new tools as developed. Moreover, to strengthen and ensure evidence based decisions by including entomology and epidemiology data in program evaluations. (PAHO, 2016d)

Source reduction relies on a behavior change and community engagement, in order to be successful and sustainable it is important to know the communities, health care providers, and politician's knowledge, attitudes, and current practices regarding mosquito control and prevention, preferred communication sources, and the current available government services. (PAHO, 2001) Knowing potential barriers and facilitators in each target area in a country will allow for a tailored approach to meet the needs of the community. Another helpful tool developed from PAHO's 2001 strategy, is the WHO's communication for behavioral impact strategy (COMBI) a method for approaching behavior changes with social mobilization and communication. (PAHO, 2001, 2016d; WHO, 2012)

Through all of these frameworks developed, PAHO acts as the technical advisor and support for countries regarding community engagement, capacity building for the health sector, surveillance, and social mobilization. Although PAHO cannot enforce any strategies or plans, that is entirely at the discretion of each sovereign nation. (PAHO, 2001, 2016d) In 2018, this was further laid out in PAHO's *Plan of Action on Entomology and Vector Control 2018-2023* plan of action document. The document proposed a plan to accelerate the control and elimination of vector-borne diseases through five strategic lines of action that would strengthen IVM and human capacity. The second line of action specifically involves engagement and mobilization of regional and local governments and communities for sustained vector control and prevention. In this action is for countries to develop effective community engagement, mobilization, and communication while paying attention to social dynamics. (PAHO, 2018b) This is where Mosquito Awareness Week fits. By providing a week for Ministries of Health to focus on the community engagement aspect of IVM through training, education, and capacity building. Aimed to accomplish behavior change for the community, healthcare providers, other ministries, and the private sector. Over time and with sustained VC efforts, the goal is for the number of arboviral disease cases and outbreaks to decrease due to the entomological decrease in *Aedes* mosquitoes.

3.1 Mosquito Awareness Week

Caribbean Mosquito Awareness Week (MAW) is a collaborative effort between the Caribbean Public Health Agency (CARPHA), Caribbean Community (CARICOM), and PAHO. The goal is to strengthen existing regional initiatives and engage the public to take action and remove mosquito breeding grounds. According to CARPHA, the initiative aims to "bring the region together to protect communities against diseases such as dengue, chikungunya, Zika spread by the *Aedes aegypti* mosquito, and malaria spread by the *Anopheles* mosquito." (CARPHA, n.d.)

The yearly initiative was started in 2016 by CARPHA due to the concurrent Zika outbreak in the Caribbean. The first MAW had 13 Caribbean countries and territories participating and focused on Zika and the associated risks for pregnant women. Due to its success, PAHO expanded the program to the entire Americas region. (CARICOM, 2016; PAHO, 2016b, 2018a) All future references to MAW are focused to the Caribbean MAW program and activities. MAW 2017 primarily focused on messaging through increasing health care workers responsibilities for disseminating information to their patients regarding personal protective measures and eliminating mosquito breeding sites. The secondary focus was on action by strengthening household and community participation in vector control. (CARPHA, 2017; PAHO, n.d. a) There was no evaluation of 2017's Mosquito Awareness Week's activities for participating Caribbean countries and territories. MAW 2018 efforts focused messages reaching the male and female heads of households to eliminate mosquito breeding sites around their homes. (PAHO, n.d. b) From the 2018 report, only six countries and territories reported participation in MAW activities. This led to MAW 2019's focus of getting VC efforts onto each Caribbean countries MoH's agenda so as to have continued education and mosquito eradication efforts.

The theme, "Small Bite, Big Treat" and the slogan, "Fight the Bite, Destroy Mosquito Breeding Sites" was the same theme and slogan as in previous years. (PAHO, 2019) Mosquito Awareness Week's intention were to educate children over 12 years of age and the heads of households regarding diseases spread by mosquitoes, how to protect from getting bitten, and identifying and removing mosquito breeding sites around the house. (CARPHA, 2019; PAHO, n.d. c, 2019) Secondary, was targeting healthcare workers, community leaders, and civil society in disease prevention and environmental protection. (PAHO, 2019) By educating and empowering people, together the Caribbean can fight mosquito borne diseases. (CARPHA, 2019) Caribbean Mosquito Awareness Week 2019 occurred 6-12 May 2019. (PAHO, n.d.c)

According to the MAW 2019 concept note, PAHO gave countries the proposal on MAW objectives, some guidelines on the communication campaign, intended audiences, as well as tips on planning, implementation, and evaluation of MAW activities. To also help countries with planning activities, a list of suggested events for the national and community level were included. But ultimately the MAW objectives, the communication and social mobilization strategies, and indicators of success were left to the countries to determine in order to better accommodate the specific needs of each country to facilitate better integration of activities. The concept note is to serve more as a call-to-action. MAW 2019's audience included the MoH and other ministries, other authorities including community leaders, the private sector, primary health care workers, vector control officers, families, and civil society organizations. Ultimately, PAHO wanted entomology and VC teams working with the communication and health promotion teams. The main objective for MAW 2019 was to increase political will for increasing vector control to promote sustained behavioral change, regarding eliminating mosquito breeding grounds, in different populations. The specific objectives included:

- For decision-makers to increase commitment to implementing policies to improve the conditions that will aid in the prevention and control of mosquitoes,
- For all countries in the region to participate and include MAW annually in official agendas, as well as to promote with regional media campaigns,
- Promote information dissemination to the community and tourists through the tourism sector and medical professionals
- Promoting social mobilization and participation of the community to eliminate mosquito breeding sites
    - Facilitate intersectoral coordination of activities for vector control
- Support the tourism sector to provide personal protection supplies against mosquitos to tourist
- Raise awareness among medical professionals as to their roles in information dissemination regarding patients' personal protection methods and mosquito breeding site elimination

4.0 Methodology

Anguilla, Antigua and Barbuda, the British Virgin Islands, Dominica, Saint Lucia, and Saint Vincent and the Grenadines were the countries in PAHO’s Barbados and ECC region that participated in Caribbean Mosquito Awareness Week 2019. These countries submitted photos, videos, and/or a report of the completed activities to the Climate Change and Environmental Determinants of Health Advisor for the Barbados and the ECC PAHO office. Additional sources included social media posts and newspaper articles reporting on the event. Activities were compiled, limitations assessed, and recommendations given for future Mosquito Awareness Week activities.

5.0 Mosquito Awareness Week 2019 Evaluation and Evidence

Table 1 List of activities performed by ECC participating in 2019's Caribbean Mosquito Awareness Week.

Country	Department	Location	Activities	Dates	Source
Anguilla	Department of Health and Protection, Health Authority of Anguilla, NHPD	Kool FM, Radio Anguilla, Upbeat and Klass FM	• Using radio for press release (13th), mosquito jingle & text messages (13-17th)	13-17 May	Submitted schedule of planned events
		3 schools	School lecture at: • St. Mary's pre-school (13th) • Orealia Kelly Primary School (14th) • Vivien Vanterpool Primary (15th)	13-15 May	
		Not provided	• Business search & destroy day	14 May	
		General Post Office, The Valley	• Community outreach awareness program	15 May	
		Scotiabank, The Valley	Community Outreach Awareness program: • Advice and instructions for controlling the spread of mosquitoes and rodents by providing instructions on traps and poisons to use • Displayed Gravid Trap (for Culex) and GAT-Trap (for Aedes) and explained how they	17 May	The Anguillian Newspaper-gave contact info for the Department at the event in case the public has questions or needs assistance

Table 1 Continued

Country	Department	Location	Activities	Dates	Source
			work • Rat poison education on toxicity and personal protective equipment • Personnel willing to assist with deterrents and gave out contact information		
Antigua and Barbuda	Ministry of Health and The Environ-ment "Join the fight and lessen the bite"	Parade through St John	Health, Wellness and the Environment Minister talked to Central Board of Health Workers: • His message: keep working hard (as part of parade) and that the diseases trying to prevent are serious and prevention makes the doctors work to treat less futile • He encouraged everyone that source reduction is possible for all to accomplish. • Mosquito jingle • Parade (NGOs and Central Board of Health Workers) to hand out placards, flyers, and banners for the anti-mosquito message	8 July	Ministry of Health and The Environ-ment Facebook posts
		Judgement Square on Market Street	Grand exhibition: • Posters of how to prevent & clear breeding sites, the	9 July	

Table 1 Continued

Country	Department	Location	Activities	Dates	Source
			mosquito life cycle, removing stagnant water & covering drums • Banner from Red Cross and USAID on protecting and preventing Zika methods • Tent with info and BTI and other larvicides/ adulticides (and instructions for use) and mosquito larvae to see, diorama of how to protect yard via source reduction		
		St. John	• Pamphlet (Zika prevention for children, elderly, and general info), flyer, leaflet handout to nearby pedestrians and drivers		
		Fort James beach in the morning and Runaway Beach in the afternoon	Beach clean-up: • Video encouraging public to carry their trash out • Video and photos of Central Board of Health Workers cleaning Beaches as part of grand litter picking exercise (50 workers and 60 bags of trash)	10 July	
		Dredgers Play-field	• Video and photos of Central Board of Health staff	11 July	

Table 1 Continued

Country	Department	Location	Activities	Dates	Source
			received certificate of appreciation (for length of service of 20 to 37 years) and gifts during MAW Sports Day • Posted PAHO's YouTube video *Rain Barrels (Together)* and *The Ross Hill Swat Club* • Videos from the MAW Sports Day (open to the public and for the vector control workers to enjoy as well)		
		Not provided	• Leaflet and flyer distribution at all major supermarkets on the island (mentioned, but no photos/videos posted)	12 July	
British Virgin Islands	Ministry of Health and Social Develop-ment, Environ-mental Health Division	Primary Schools on Tortola island (grades 2-4) Francis Lettsome Primary School grounds	80 students participated • Describe diseases transmitted by *Aedes aegypti* • Teaching the mosquito life cycle & observe larvae and pupae • "Mosquito Breeding Sites Treasure Hunt" activity	6-12 May	Submitted video & report
		Ivan Dawson Primary School grounds	48 students participated • Discuss importance of destroying mosquito breeding		

Table 1 Continued

Country	Department	Location	Activities	Dates	Source
			sites • Student & teachers discussion on mosquitoes • ”Mosquito Trivia” winners got a certificate		
		Joyce Samuel Primary School grounds	52 students participated • Discussing mosquitoes’ potential breeding sites • Talking to students & teachers (students seeing larvae & pupae)		
		Mosquito Exhibition in Road Town	• Explaining mosquito life cycle to public • Handing out pamphlets • Model house showing potential breeding sites (and life cycle) • Talking to public • Have a fogger and insecticides along with pamphlets and mosquito larvae/pupae for people to see	12 May	
Dominica	Environ-mental Health Department	Castle Bruce Platform (Playing field), Weirs Flat in Marigot, Bath Estate, & Anse de	• Mosquito Drum proofing (Supported by National Pest & Termite Control Ltd. Dominica Red Cross, and the Health Promotion Unit)	6-10 May	Submitted report and photos

Table 1 Continued

Country	Department	Location	Activities	Dates	Source
		Mai Flat			
		Castle Bruce Primary School	• Tire painting		
		Schools in their usual classrooms in Roseau Health District, Wesley Health District, Portsmouth Health District, & St. Joseph Health District	• Mosquito Education Awareness (health education sessions at): • Awareness on: mosquito life cycle, breeding sites, diseases, and prevention tips, also observe larvae and pupae • Use of PAHO's SWAT Workbook • Certification of participation awarded at Salybia Primary School		
		Convent High School grounds	• Mural painting depicting mosquito breeding sites by the High School's 4-H club (Sponsored by the Dominica Red Cross)		
		Kingshill	Mosquito Drive: • Vector control surveillance in the community by the Environmental Health officers and Vector Control Officers • Education material distributed to households		

Table 1 Continued

Country	Department	Location	Activities	Dates	Source
			Open Air Meeting: • Education session on mosquito control and waste management (Soufriere Village Council collaborated)		
St. Lucia	Department of Health and Wellness, Environ-mental Health Division; Training also by Bureau of Health Education, Saint Lucia Solid Waste Manage-ment Authority, Substance Abuse Secretariat	Anse La Raye Constituency Council	VC training, 15 participants trained • Trained on how to analyze collected data and plan appropriate interventions • Drafted sustainable VC plan, agreed by both the council and Environmental health division	2-5 July	Submitted report on July 19, 2019
		Castries Southeast Constituency Council	• VC training	23- 26 July	
		Vieux Fort & Dennery Constituency Councils	• Last 2 VC trainings (no further data available)	August 2019	
St. Vincent and Grenadines	Ministry of Health Wellness & the Environ-ment	Various primary schools in their usual classrooms	Health education sessions on Leeward coast, St. Vincent: Spring Village Methodist, West Wood Methodist, Troumaca Primary, Fitz Hughes Primary, and Chateaubelair Primary School • Lectures (with information	6 May	Submitted video and report

Table 1 Continued

Country	Department	Location	Activities	Dates	Source
			handouts), mosquito identification (microscopes)		
		In students' usual classrooms	Health education session at Paget Farm Primary School in Bequia: • Lectures (with information handouts), mosquito identification (microscopes)	7 May	
		Done in various communities across St. Vincent	• Whistle stop on Leeward Coast, St. Vincent starting at Layou and Barrouallie		
		In students' usual classrooms	Health education session on Windward coast, St. Vincent (Georgetown Primary, Dickson Primary, Langley Park Primary, Tourama Primary, and Sandy Bay Primary school) • Lectures (with information handouts), mosquito identification (microscopes)	8 May	
		Union Island	• Health Fair at the Captain Hugh, Mulzac Square in Clifton		
		Done in various communities	• Whistle stop starting at Owia	9 May	

Table 1 Continued

Country	Department	Location	Activities	Dates	Source
		across St. Vincent			
		Port Elizabeth	• Health fair		
		Done in various communities across St. Vincent	• Whistle stop in Georgetown area	10 May	

From the submitted documents, Saint Lucia was the only country that developed several specific objectives: to reduce the vector population by 25% and to train 70 constituency council members in the targeted communities by September 2019. The British Virgin Islands, Dominica, and Saint Lucia listed objectives in their report congruent with the concept note. The communication slogans and themes were the same on all the participating islands. The British Virgin Islands added to the MAW slogan “Protect yourself, reduce mosquito breeding sites, and keep mosquitoes out.” Saint Vincent and the Grenadines ended their submitted video with “Our Health is a Shared Responsibility.” Lastly, Antigua and Barbuda used “Small bite, big threat. Join the Mosquito Fight and Lessen the Bite.”

All activities submitted by the participating countries are included in Table 1. The use of audio messages was not as pronounced in the reports as in previous years’ activities. Yet, as in 2016, Anguilla used radio messages and text messages to reach the entire island. This year Antigua and Barbuda used PAHO’s Mosquito jingle during their activities and parade as well as posted PAHO’s YouTube videos *Rain Barrels (Together)* and *The Ross Hill Swat Club* on the Ministry of Health and the Environment’s Facebook page.

Anguilla, the British Virgin Islands (BVI), Dominica, and Saint Vincent and the Grenadines had children focused health education sessions located in schools. BVI mentioned they focused on school aged children due to previous experiences showing school aged children retain the information and pass it to other household members. Anguilla only mentioned they visited three schools during MAW 2019. BVI (visited three primary schools), Dominica (visited four schools), and Saint Vincent and the Grenadines (visited ten schools) elaborated more as to the curriculum of their health education sessions. Common was education on identifying *Aedes aegypti* mosquitoes, the mosquito life cycle, diseases transmitted by mosquitoes, how to identify common breeding grounds and the importance of cleaning your surroundings, and how to protect yourself from being bitten. Additionally, students were able to observe live mosquito larvae and pupae. Health education sessions were taught by Environmental Health Officers (EHO) and/or Vector Control Officers (VCO) either in the student's classroom or on the school grounds.

Specific to BVI's health education sessions the Environmental Health Division staff and VCOs explained their roles and responsibilities regarding mosquito control. As part of the session, students were encouraged to share prior knowledge on mosquitoes. Included in the session was a model house with some commonly found items to display mosquito breeding sites. Prior to the health education sessions, the VCO and Environmental Health Division staff went around Francis Lettsome school grounds to stage, and in some cases use existing, mosquito breeding containers to be used in a "Mosquito Breeding Sites Treasure Hunt." Students organized into groups with an Officer as team leader. The group who found the most breeding sites received a certificate of achievement for outstanding vector control activities. The other schools visited on BVI did not do a treasure hunt due to the weather and instead participated in group trivia on what was discussed during the health education sessions. The winning group also received a certificate of achievement.

BVI deemed Mosquito Awareness Week 2019's health education sessions in schools a success that will continue in future Mosquito Awareness Week programs.

Dominica kept the same focus as in 2016: health education in schools and mosquito proofing barrels (mentioned below). Dominica's Mosquito Education Awareness was led by EHOs and certificates of participation were handed out to students at Salybia Primary School and Castle Bruce Health District. Also part of the mobilization efforts in Dominica included painting a mural depicting mosquito breeding sites, completed by the Convent High School 4-H club and sponsored by the Dominica Red Cross. Additionally, Dominica's Castle Bruce Primary School painted some used car tires. The end goal of the painted tires was not described in the report or alluded to in the photos. It is possible they were used for gardening efforts as has been seen on Caribbean islands. From the video Saint Vincent and the Grenadines submitted, it appeared as if while doing the health education sessions on the school grounds the Officers also talked to community members who approached them.

Community education efforts appeared to be another common activity among the participating countries. Antigua and Barbuda's community education included a parade of NGOs and the Central Board of Health Workers staff who all handed out flyers to pedestrians. The parade was attended by the Health, Wellness and the Environment Minister who encouraged workers to continue source reduction to prevent diseases. They also handed out flyers at major supermarkets on the island. Additionally, Antigua and Barbuda hosted a Grand Exhibition with posters on how to prevent and clear breeding sites, the mosquito life cycle, and to remove stagnant water and cover drums/barrels. Part of the Grand Exhibition included information on larvicides and adulticides, observable mosquito larvae, and a diorama of how to do source reduction to protect your home. To celebrate their staff, they initiated MAW Sports Day where Central Board of Health Staff and the community could play sports together. During the MAW Sports Day, the Central Board of Health Staff who worked 20 to 37 years were given a Certificate of Appreciation.

Anguilla's Community Outreach Awareness program involved displayed traps and poisons with advice and instructions for controlling the spread of mosquitoes and rodents. BVI hosted an exhibition located in a high traffic place and used a tent sponsored by the BVI Digicel branch. In addition to the same information presented at Antigua and Barbuda's exhibition, BVI presented insecticides, fogging machines, screens, repellent, observable larvae and pupae, and the same model house as used in the school's Health Education Session. BVI mentioned they handed out over 300 educational brochures during the exhibition and reported community members were impressed and approved the efforts taken by the VCOs in preventing mosquitoes. Dominica also hosted an education session focused on mosquito control and waste management with the collaboration of the Soufriere Village Council. Lastly, Saint Vincent and the Grenadines hosted a health fair on Union Island to hand out information, with no specifics mentioned.

Dominica's other focus, mosquito proofing drums, occurred in Bath Estate (13 drums), Marigot (30 drums), Anse de Mai (31 drums), and Castle Bruce (20 drums) with a total of 94 mosquito proofed drums. The event was supported by National Pest & Termite Control Ltd., Dominica Red Cross, and the Health Promotion Unit. Additionally, the Dominica Red Cross donated the material to mosquito proof 20 drums in Bath Estate. From the pictures submitted, it appears as if Dominica had about 5 to 10 individuals attend each mosquito proofing drum session.

Saint Lucia focused entirely on capacity building through education in four high risk communities to address the high incidence of vector-borne diseases and waste management issues. Only one community's Constituency Council, Anse Le Raye (15 participants), had completed the training. The training involved 1 to 3 days of classes covering nine courses: Introduction to Vector

Control, Mosquito Biology and Control, Vector Borne Diseases 1 (Mosquito Borne Disease), Rodent Biology and Control, Vector Borne Diseases 2 (Rodent Borne Disease, Leptospirosis), Integrated Vector Management, Use of Personal Protective Equipment, Environmental Factors Contributing to Vector Borne Disease, and Effective Communication and Substance Abuse. On training day 4 participants walked through the community to inspect for mosquito and rodent control opportunities. Additionally, the participants were trained to analyze data and plan an appropriate intervention as well as to draft a sustainable VC plan to be agreed by both the Council and the Environmental Health Division. The other targeted communities were scheduled to begin training at the end of July 2019 and in August 2019. Further reports and information was not available as such it is not currently possible to determine if Saint Lucia meet their specific objectives.

Another common activity included clean up and VC surveillance of communities. Anguilla hosted a Business Search and Destroy Day, again there was no report elaborating on the activities performed. Antigua and Barbuda's Central Board of Health Workers gathered 60 bags of trash from two beaches. Dominica's Mosquito Drive involved EHO and VCO inspecting 20 premises and handed out education materials. Lastly, Saint Vincent and the Grenadines did "Whistle Stops" which involved walking around neighborhoods on Saint Vincent handing out information packets. Additionally, an Officer dressed as a mosquito and visited several preschools and local shops.

6.0 Mosquito Awareness Week 2019 Discussion

The inaugural Mosquito Awareness Week was established concurrent with the Zika outbreak in 2016. (CARICOM, 2016; PAHO, 2016b, 2018a) The Caribbean Mosquito Awareness Week is a collaborative effort between CARICOM, CARPHA, and PAHO to strengthen the existing regional vector control initiatives and engage the public to take action to remove mosquito breeding grounds. (CARPHA, n.d.) The main objective for MAW 2019 was to increase political will for increasing vector control to promote sustained behavioral change for eliminating mosquito breeding grounds in different populations. The countries that participated completed a variety of activities focused primarily on educational activities in the community and at schools. The British Virgin Islands mentioned they focus activities on school aged children due to previous experiences showing school aged children retain the information and pass it to other household members. By investing behavior change in children now, there is a greater change of sustained behavior change.

The British Virgin Islands are the only country that included country specific recommendations, based on 2018 and 2019's activities, for future BVI MAWs. They recommend to plan for February instead of April and to include more islands such as Anegada, Virgin Gorda (including partnering with their BugOut initiative), and Jost Van Dyke. For all the remaining recommendations BVI would like VCOs to be more involved as their roles and responsibilities takes them into the communities where the public interacts with them. Additionally, BVI wants to hand out repellents, mosquito screens, and larvicides in addition to pamphlets. Further, BVI would like to design more user friendly pamphlets that include an activity related to identifying mosquito breeding sites. BVI desires to contact more public and private schools and to develop new ways for more student engagement, e.g., drawing the mosquito life cycle, a slogan competition, a mosquito awareness parade, and a short inter-school competition on vector control activities where the winners receive trophies from the Environmental Health Officers. Additionally, BVI would like to have a larger exhibition in collaboration with other governmental agencies and schools. The exhibition would have multiple stations displaying mosquito larvae, mosquito transmitted diseases, the three forms of control (chemical, biological, and physical), and other ideas as conceived. In addition to all the recommendations, BVI would like to reach more of their population. They propose using more media sources (TV, social media, and radio) as well as to have an interactive question and answer segment on the radio. While this is specifically mentioned by BVI, other countries could benefit from these recommendations as well.

Regarding the British Virgin Islands desire to change the month of Mosquito Awareness Week activities, if MAW is on the Ministries of Health's agenda in each country, then each country will have to approve a budget, human resource allocation, and planning for the activities and as such can plan the timeline to suit their specific needs. Additionally, as *Aedes* mosquitoes do not rely on rainfall for breeding sites and mosquitoes are present year round in the tropics, MAW activities can occur at any time of year in order to fit around other programs. (Klitting, et. al., 2018, Paupy, et. al., 2009; Simmons, 2012) PAHO setting the second week of May serves as a call to action and sets a goal of when to complete implement planned activities. This year's MAW activities were completed by countries in May, June, and August (Table 1). In the 2016 Mosquito Awareness Week Report, it was noted that the original date was set for February yet being so early in the year it did not lend enough time for planning and implementation and thus future MAWs were set for April.

Saint Lucia and Antigua and Barbuda's activities appeared to focus less on education of school-aged children, which may be due to the Ministry of Education not allowing participation.

With the success other islands are having with this activity, if Saint Lucia and Antigua and Barbuda want to include school-aged children in their target population, it is recommended they contact Anguilla, BVI, Dominica, and Saint Vincent and the Grenadines regarding how they have successfully implemented visiting schools and collaborating with the Ministry of Education. Additionally, Dominica's activities involved the collaboration with an NGO and a private business. Other countries may desire to contact Dominica to assist in methods for creating collaborations with other local organizations and businesses.

Antigua and Barbuda's Central Board of Health staff performed the beach clean-ups. It is recommended they encourage participation and education of the community on such activities. Doing so can build capacity and engage the community to keep their homes and communities free of mosquito breeding sites. There were some valid critical comments as well as supportive comments on Antigua and Barbuda's Ministry of Health and the Environment's MAW activities Facebook posts. The commenters essentially wanted more sustainability by enforcing fines, having public trash bins available, and to engage the community instead of just having the Ministry staff cleaning beaches. Without community capacity building and public trash bins it is possible the beaches and other community locations will be littered again. Placing public trash bins may require hiring more personnel to remove the trash. Another possibility is to promote a partnership with waste management services to donate the bins and help with trash removal or even enforcing a small littering fine that will cover installation and maintenance costs of garbage bins.

Some recommendations from the 2016 and 2018 reports are still applicable for 2019 (again, there was no 2017 report). In 2018 there was a recommendation to include Town Hall meetings so as to talk with the community and distribute education pamphlets. This too is a way to reach the community to discuss mosquito awareness and VC as well as to inform the needs of the community and tailor the program. As there are still some arboviral cases being reported in the Caribbean and with dengue's endemo-epidemic cycles, it is important to continue Mosquito Awareness Week efforts towards behavior change and improving source reduction.

MAW 2016's recommendation to develop a strategy for collecting quantitative data on the impact and sustainability of the campaign is still valid. It is recommended to conduct a process and outcomes evaluation by determining indicators of success, finding or creating appropriate measurement tools, then collecting and evaluating data. Recommended measurement tools include key informant interviews of Vector Control officers and/or anyone implementing and operating the activities, interviews with non-participating countries, pre-post surveys of participants, systematic entomologic surveillance, and systematic epidemiologic surveillance. The goal would be to determine barriers and facilitators to program implementation and operation, determine correct knowledge retention, and determining program effectiveness. The evaluation report can be used to identify areas of improvement for future programs.

Regarding the media mentions, PAHO's Assistant to the Country Program Specialist who are located in each country in the Barbados and ECC region were contacted to assist in providing local media mentions of MAW but none returned contact. This would be beneficial to assess the levels of media communications within countries and aid in understanding the programs reach.

Limitations specific to Saint Lucia include low levels of literacy and education level, as determined by a pre/post-test. Additionally, they noticed more engagement when the lectures were in the Kweyol language. As Saint Lucia had three more Constituency Council's to train, there was time to adjust the language and literacy level in the curriculum. Due to not receiving a follow up report, it is not known if changes were made and if so, were they more successful. As previously mentioned, Antigua and Barbuda's Central Board of Health Staff performed the beach clean-up.

By not including the community in vector control operations it limits their capacity and the level of sustainability. Further, as there is no requirement on what to report to PAHO, there is no consistency on what information regarding the activities are reported.

It would be beneficial to discuss with non-participating countries to understand their reasons and barriers to MAW participation. Some potential reasons why countries have not participated in 2019's Mosquito Awareness Week may be due to a focus on other diseases and health issues, the perception of low risk to arboviral diseases due to the overall trend of decreasing number of cases over the last year or two, or the time of the year for the activities. As already mentioned, by getting MAW on the MoHs agenda a budget and planning for the event is more likely. A budget can help cover the costs of printing pamphlets and posters, of which PAHO has the infographics listed online available for free. (PAHO, n.d. i) Additionally, MAW being on the agenda can alleviate insufficient human resources or competing priorities for human resource through resource allocation. Another potential barrier is the possibility of a lack of intersectoral collaboration at the higher governmental levels, such as needing the Ministry of Education's involvement along with the MoH in order to plan and implement activities with schools. Along with the recommendation to include VCOs in more activities, it could be that those individuals may need more training on how to engage different target populations, such as children, parents, business owners, and those in the MoH or other ministries.

Further, there were no activities aimed at the tourism industry and there may need to be more training of MoH and/or VCOs to engage tourists along with the need to collaborate with other sectors and other country's governments. Additionally, as a region with a tourism-based economy this would be a large and population to target and as previously mentioned malaria followed by dengue is most diagnosed cause of fever in tourist returning from LMICs worldwide indicating a population that would benefit from MAW activities. (WHO, 2019a; World Travel and Tourism Council, 2019) Moreover, tourist may be coming from arboviral non-endemic areas and thus may not know to perform important prevention methods, such as using mosquito repellent, to wear long sleeves and pants, or to use AC when available or stay in housing with screened windows. To reach this population, educational materials and mosquito repellent can be provided at airports, seaports, car rental locations, hotels, tour agencies, and at major tourist attractions and shops

From all the MAW participating countries, there is no mention of a number of schools and participants in the activities and so there is no way to determine what percentage of the target population has been reached. This information can determined the level of coverage by the activities and where to concentrate efforts in the following years. Lastly, mentioned in the Mosquito Awareness Week 2019 concept note was to conduct a national entomological survey to assess the entomological risk of communities. By doing so, the MoH will be able to determine which areas need to be focused on for MAW activities and guide what activities are planned. This information along with a follow up survey can show the benefits of community engagement in VC and the data may be convincing for communities towards VC sustainability.

6.1 Public Health Recommendations

Arboviral diseases such as dengue, chikungunya, and Zika viruses all contribute to high morbidity in the Caribbean. (Brathwaite, et al., 2012; Paupy, et al., 2009; Webb, 2016) Everyone is at risk to arboviral disease to a varying degree dependent on the region’s rainfall, temperature, and environmental sanitation. (Paupy, et al., 2009; WHO, 2019a) Outbreaks from these diseases also negatively affect economies and families. (Weaver, et al., 2016; WHO, 2019a; Yactayo, et al., 2016) Additionally, these viruses are transmitted by the same domiciliary mosquito with a preference for urban and peri-urban breeding sites. (Klitting, et al., 2018; Ngoagouni, et al., 2015; Paupy, et al., 2009; Powell, et al., 2013; PAHO, n.d. e; WHO, n.d. a) Since the beginning of the 21st century, PAHO and the WHO have developed strategies and frameworks aimed at improving current mosquito prevention and control efforts. Fundamental to the strategy/frameworks is an escape from vertical programs and to include community participation as well as social communication and advocacy in an integrated vector management program. (PAHO, 2001)

Due to the preferences of the *Aedes* mosquito, the arboviral disease prevalence and potential for outbreaks, and the lack of licensed vaccines available in the Caribbean (except in U.S. and European territories), the WHO, PAHO, and the CDC all recommend vector control for the protection of all populations. More specifically source reduction or environmental management methods is the most effective method with the biggest impact for reducing the number of mosquito breeding sites and thus mosquito population control. (CDC, 2017b; PAHO, 2016a; Paupy, et al., 2009; Webb, 2016; WHO, n.d. a; ECDC, 2016a, 2016b) The domiciliary life of *Aedes* mosquitoes indicates the need for households to take the responsibility of vector control. Further, the whole community needs to participate in VC since one property not participating in source reduction and VC can sustain mosquitoes and thus disease transmission. (Paupy, et al., 2009; Weaver, et al., 2016) Additionally, it is easy to imagine that if mosquitoes are always prevalent, that people could feel as if VC is impossible to accomplish. Conversely, motivation for mosquito control can also be due to the nuisance of mosquitoes and less due to the concern for acquiring and transmitting arboviral diseases. (Guzman, et al., 2010) Programs such as Mosquito Awareness Week, can be a source of education and capacity building by reaching out and engaging the community as well as building intersectoral relationships to strengthen and sustain the VC efforts. Moreover, each Caribbean country will have to evaluate what is feasible, practical, and acceptable for their needs, while also understanding continued VC efforts are effective but require sustained messaging, even more so for the time-consuming efforts such as source reduction.

VC includes, but is not limited to, larval source reduction or ‘cleanup’ campaigns via removing standing water sources around the house, schools, public spaces, cemeteries, and businesses weekly as well as removing unused containers and protecting used containers from becoming mosquito breeding sites. (Guzman, et al., 2010; Paupy, et al., 2009; CDC, 2017b; PAHO, 2016a; WHO, n.d. a) This includes rainwater barrels being protected with appropriate screens. PAHO has created a video, located on their website, on how to properly protect rainwater barrels from becoming mosquito breeding sites. (PAHO, n.d. b) Any water sources that cannot be removed or covered, such as water for livestock and companion animals, should be thoroughly and regularly scrubbed and to not solely rely on biological or chemical control mechanisms. This is because *Aedes* mosquito eggs attach to the container and once the eggs contact water they will hatch. (Powell, et al., 2013; PAHO, 2016a; ECDC, 2016b, WHO, 2019a)

Other forms of vector control includes chemical controls such as larvicides and adulticides. (Guzman, et al., 2010) Adulticides are often used for space spraying or fogging. This method is not sustainable long them and to be most effective the insecticide needs to contact all surfaces. (PAHO, 2001) As such, space spraying typically is best left to use during outbreaks or when the adult mosquito populations are higher due to the failure of larval source reduction. (Paupy, et al., 2009) Although exploring other options before using space spraying is best due to insecticide resistance in *A. aegypti* worldwide. *A. albopictus* is still susceptible to insecticides, but due to their more diverse larval breeding sites it is more difficult to spray and clean all potential sources. (Hemingway, et al., 2009; Paupy, et al., 2009)

Biological control methods typically work better for mosquito control and prevention than chemical methods and with less risk of mosquitoes developing resistance. Further, chemical controls need to be reapplied appropriately to properly work. (Guzman, et al., 2010; Paupy, et al., 2009) Biological controls include, but not limited to, genetically modified mosquitoes, sterile mosquitoes, *Wolbachia* infected mosquitoes, and larvivorous fish and copepods. (Guzman, et al., 2010; Paupy, et al., 2009; Simmons, et al., 2012; Ye, et al., 2015) The genetically modified mosquitoes are males that sterilize the wild-type female mosquito population. This method reduces the female's egg output and therefore the size of the next generation. (Wise de Valdez, et al., 2011) *Wolbachia* is an obligate intercellular bacteria which is introduced into mosquitoes and has been shown to prevent dengue and chikungunya infections, thus preventing the spread of these disease to humans. Further, these mosquitoes can interact with wild-type mosquitoes and spread *Wolbachia* to the wild-type mosquitoes. (Moreira, et al., 2009; Ye, et al., 2015) The biological control methods still require effectiveness studies in different populations as well as addressing the concern of ethics and risk management. (Paupy, et al., 2009) There has been demonstrated effectiveness in insecticide treated curtains and water container covers in Mexico and Venezuela as well as using dominant lethal gene in mosquitoes, where the offspring with wild-type females result in death. (Kroeger, et al., 2006; Wise de Valdez, et al., 2011) Importantly, biological controls require facilities and expertise and more so for the ones that need to be frequently re-introduced such as the larvivorous fish, copepods, and sterile mosquitoes. (Guzman, et al., 2010) Therefore the importance of knowledge regarding disease epidemiology and entomological monitoring in order to properly allocate resources. (Simmons, et al., 2012) Moreover, with all the control methods, there is the need to educate the public on when and how to use the methods, how to determine which methods are best for each household, school, business, etc., as well as to leave larvivorous fish to do their role in larval control and to not eat or keep the fish as pets.

Environmental management to reduce mosquito breeding sites can be performed at the individual, interpersonal, and community level in the social ecological framework such as source reduction or it can be at the institutional and policy level such as improvements to clean water and proper waste management services. Yet these improvements and changes require huge investments in infrastructure in order to increase the reach of safe water and solid waste disposal. This can be a concern if cost recovery mechanisms are put in place, such as metering water use which might encourage the return to collecting rainwater. (Guzman, et al., 2010) Thus it is important for intersectoral collaboration and for public health officials to work with ministries and civil society on infrastructure development. Even with improved water and sanitation it is still important to participate in other aspects of vector control and protection as behavior changes will aid in achieving long-term control of mosquitoes. (Guzman, et al., 2010)

Health care systems can be stressed due to the unpredictability of outbreaks and developing severe dengue. (Simmons, et al., 2012) As such, it is important for individuals to understand signs and symptoms of arboviral infections and to seek prompt and proper medical attention. Ideally, primary care health professionals and to reserve hospitals for severe cases. The primary care health professionals should be trained on monitoring cases and the facilities should have the capacity for rapid ambulatory response as severe dengue can develop quickly. (Guzman, et al., 2010; Simmons, et al., 2012)

Further assistance in rapid response would be improving early diagnosis and predicting the risk of developing severe dengue. (Simmons, et al., 2012) Thus the need for more specific and sensitive diagnostic methods such as multiplex RT-PCR to detect virologic mono-infections and co-infections, PRNT or IgG ELISA to determine exposure serologically, as well as developing tests for other specific biomarkers of infection. (Ariën, et al., 2018; Guzman, et al., 2010; Kindhauser, et al., 2016; Waggoner, et al., 2016; WHO, 2019e) The tests should be commercially available and be able to be used at the point-of-care. (Guzman, et al., 2010; Sanofi, 2019) Proper training to run and interpret the results is necessary with any new equipment or method and commercially supplying companies offer troubleshooting assistance. Further, primary care facilities as well as hospitals should have the capacity to operate point-of-care diagnostic tests. Diagnostic tests are important for properly identifying the target population for Dengvaxia. (Ariën, et al., 2018; WHO, 2019e; Sanofi, 2019) More specifically, the WHO recommends viral diagnosis of acute dengue as once vaccination becomes more prevalent, serologic diagnosis can increase the false-positive rates. (WHO, 2019e) Sanofi is currently working on a point-of-care serological test that will be high sensitivity, so as to properly identify those with a previous dengue infection, and high specificity, to avoid vaccinating false positives and thus increase the risk of developing severe dengue. (Sanofi, 2019) The WHO also considers it acceptable to have quality hospital records of dengue cases to determine who is eligible for Dengvaxia vaccination. (WHO, 2019e)

As mentioned above, there is a passive system already in place for the Americas region where Ministries of Health submit the numbers for suspected, confirmed, and imported cases to PAHO which is then reported back out via PLISA. This surveillance data is by country and by week. (PAHO, n.d. f) By having a common location for all the county data, there is a standardized case definition which enhances the ability for data sharing. Yet, as the PLISA data is aggregate, it makes it difficult to know where to prioritize finite resources within a country, thus higher resolution data is more desirable. Further, as mentioned above countries do not have incentive to report cases for fear of losing tourists. To increase reliability of the data would mean increasing costs by making the system active surveillance or by having a regional requirement for accurate data submission to PAHO. A resource already available is CARPHA, a regional organization where Caribbean countries pool resources for the benefit of all their member states, offers capacity building in numerous areas including surveillance data and GIS (Geographic Information System). (CARPHA, n.d. a) PAHO is another already available resource, which acts in an advisory role and also provides some financial assistance.

In order to understand where increased efforts are needed there needs to be a strong surveillance system in use. The improved diagnostics and a strong surveillance system are important due to the prevalence of numerous arboviral diseases with similar clinical symptoms in the region. (WHO, 2019e) Additionally, as these arboviral diseases have asymptomatic cases which leads to silent transmission and allows for accelerated disease transmission and geographical spread. Thus, necessitating a strong surveillance system that can aid in rapid identification and response to outbreaks. (Duong, et al., 2015; Nguyet, et al., 2013) Moreover, long-term, quality epidemiologic data is important for understanding if interventions are effective and more so as dengue has an endemo-epidemic cycle with higher cross-protection occurring after outbreaks. (Clapham, et al., 2017) For the current dengue vaccine, Dengvaxia, epidemiologic data can help determine which age range each country should target based on previous exposures so as to minimize risk of severe dengue cases. The surveillance systems also can aid in determining vaccination program impact, duration of immunological protection, and evaluating the vaccination schedule (as 3 doses can be a barrier for some individuals). (WHO, 2019e) Most important, regarding the dengue vaccine is the development of a safe, effective, and affordable vaccine that does not depend on known serostatus and produces life-long immunity to all four serotypes in one dose.

All aspects of IVM, as described above, require good and transparent communication. Communication and data can aid in setting up intersectoral collaboration, advocating to ministries and the community the importance of VC, and for educational purposes. There needs to be a recognition of the significance of arboviral diseases leading to the commitment to IVM practices including the collaboration with other countries. Increased ministerial support includes using available tools, such as GIS and larvicides, as well as supporting research for other VC practices, improving organization of services, and making smart partnerships to accomplish IVM practices. (Guzman, et al., 2010) For Dengvaxia, it is important for citizens to know, from their ministers, the vaccination process, associated vaccination risks, and that the continuation of VC practices and prevention methods are still vital regardless of vaccination status. Further, individuals need to have confidence in their country's national vaccination programs and accept the vaccine's benefits and risks. If the risks are not accepted, the cases of severe dengue can erode the public's acceptation of the dengue vaccine and other vaccines in the program. (WHO, 2019e) The WHO recommends, ministries find ways to cover the cost of the any arboviral vaccine and serologic tests prior to Dengvaxia inoculation and not at the expense of other public health programs, in order to decrease any potential inequities. (WHO, 2019e) Other forms of risk communication messaging can include printed materials and radio messages aimed at airports, seaports, and densely populated areas so as to reach tourists and locals. (Simmons, et al., 2012) As mentioned above, PAHO has communication materials on the Caribbean Mosquito Awareness Week website. These materials are free to use in print and on social media. Additionally it is important to know the target audience's preferred method of communication to increase reach as well as knowledge gaps. This information can come from KAP (knowledge, attitudes, and practices) studies. KAP studies can also inform on program participant's retention of educational key points to aid in improving subsequent programs and educational materials.

Specifically for Zika, there needs to be messaging, education, and access to family planning due to sexual transmission in addition to messaging and education for preventing mosquito transmission. (CDC, 2017c) It is important for health care providers in addition to VCO/EHOs to communicate the risks and prevention methods to women and their partners who are pregnant or trying to get pregnant. (WHO, 2018b) Thus, all pregnant women, women trying to get pregnant, and their partners should avoid areas known to have Zika or take the necessary steps to avoid being bitten by mosquitoes, including sleeping under mosquito nets when sleeping during the day. In addition, during pregnancy women should abstain from intercourse or using a condom. Those trying to conceive and have traveled to ZIKV endemic areas should wait the appropriate length of time for a presumptive infection to be cleared; women should wait two months and men, three months. (CDC, 2017c; WHO, 2018b, 2019f) Other general protective measures to prevent being bitten by mosquitoes and prevent disease transmission includes promoting the use of personal protective measures such as wearing long sleeves and pants, using mosquito repellent, and using screens on windows and doors or using AC if available. (Paupy, et al., 2009; CDC, 2017b; PAHO, n.d. e)

Due to the regional history of failed interventions to remove or inhibit the spread of mosquitoes, even when vaccines are readily available, there will still be a great need for continued and vigilant vector management, timely diagnosis, and epidemiologic and entomologic surveillance to protect all populations by reducing morbidity and mortality. (PAHO, 2016d; Webb, 2016) It is necessary to have ministerial support and an intersectoral approach with the appropriate ministries, health care professionals, and public health professionals collaborating on developing plans and resource allocation for handling concomitant arboviral outbreaks, seasonal illnesses, and natural disasters. Doing so would require quality, higher resolution surveillance data with proper educational materials and capacity building for the community.

Appendix A 2019 Caribbean Mosquito Awareness Week Media Mentions

- https://theanguillian.com/2019/05/mosquito-awareness-week-vector-control-meets-the-public/ (Anguilla)
- https://www.facebook.com/investingforwellness/ (Antigua and Barbuda)
- https://abstvradio.com/mosquito-awareness-week-a-success/ (Antigua and Barbuda)
- https://www.nationnews.com/nationnews/news/239638/mosquito-awareness (Barbados)
- https://m.facebook.com/story.php?story_fbid=10213881638130758&id=1102627985&sfnsn=mo&s=100035315014849&w=n (BVI)
- https://www.nationnews.com/nationnews/news/239710/carpha-fight-bite (CARPHA's article in Barbados)
- http://drealfmgrenada.com/index.php/2019/05/14/carpha-urges-the-region-to-deal-seriously-to-eradicate-mosquitoes/ (same CARPHA article in Grenada)
- https://www.dominicavibes.dm/news-257939/ (Dominica)
- https://kairifm.com/dominica-observes-mosquito-awareness-week-2019/ (Dominica)
- https://drive.google.com/file/d/1QKNqYCD1_n_6ATlLifSMbBVUMsSmGrAy/view (Saint Vincent and the Grenadines)

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