The Rise of Vector Borne Diseases: How the Increased Spread is Bugging the World

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Table of Contents

Preface

‘Small Bites, Big Threats…’

To many people, mosquitos and ticks are not huge fear factors. They are considered to be a nuisance, an annoyance or at most, pests. Many people fear sharks or snakes more than they would a miniscule bug. However, for one death due to a shark attack, there are more than 68,750 deaths caused by mosquitoes (see figure 1). This is a number that is rising by the day due to various vector borne diseases. These deadly diseases come from primarily mosquitos and ticks but they can also originate from flies and fleas. Canada and Sweden, countries that have never in the past had any instances of vector borne disease, now are having increasing outbreaks. Currently vectors are winning in the fight against humans. The treatment methods humans are attempting to come up with are unreliable and are usually only effective for a few years. Instead of “zapping the bugs”, humans are actually “feeding them”. They are making the world climates warmer and more comfortable for the vectors to strive in. Humans are moving closer together, in unfavourable sanitary areas, allowing vectors to feed faster and rapidly infest their houses. Unwillingly, humans are transporting the vectors in planes and boats to allow them to feed on new victims. Vectors are undoubtedly a serious problem but they are fueled by humans that significantly accentuate this crisis. The world’s population needs to stop “feeding vector opportunities” so vectors can stop “feeding on the world”. Welcome to a paper dedicated to the rising world issue of vector borne diseases.

Definition/Significance

Some of the smallest animals on the planet are the biggest killers. Vector borne diseases account for seventeen percent of infectious disease, causing more than seven-hundred thousand deaths annually worldwide (see appendix figure 1,2) .[1] Despite the issue being so prevalent, very few people are aware of what a vector is. In both biology and physics, a vector has a direct relation to movement. The biological definition of a vector is a living organism that can transmit infectious diseases from human to human or from animals to humans. Vectors are classified as arthropods with the features of being; cold- blooded, small in size and usually blood sucking. The majority of vectors transmit infections by bites. A vector does not directly cause diseases but instead transports them from one host to another. The most common vectors are mosquitos and ticks.

Unlike vectors, a disease is a commonly known term. However, it needs further clarification. Biology online defines a disease as an abnormal condition of an organism which interrupts the normal bodily functions that often leads to a feeling of pain and weakness and usually associated with signs and symptoms.[2] One major type of disease is called an infectious disease. An infectious disease is caused by organisms such as bacteria, viruses, fungi or parasites.[3] Vector borne diseases are a strand of infectious diseases.

The fundamentals of how most vectors transmit diseases are by sucking blood and ingesting pathogens from one host. The pathogens (something that can produce a disease), will multiply and then be inserted into another host. Common diseases that vectors give to humans include malaria, dengue fever, chikungunya, zika virus, yellow fever and lyme disease.

Malaria is the most recognized vector borne disease. There were approximately 219 million malaria cases worldwide in 2017 in 87 countries; with 435 000 of these cases being

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[1] "Vector-Borne Diseases." *World Health Organization*, World Health Organization, 2017, www.who.int/news-room/fact-sheets/detail/vector-borne-diseases.

[2] Customers. "Disease." *Biology Online*, 12 May 2014, www.biology-online.org/dictionary/Disease.

[3] "Infectious Diseases." *Mayo Clinic*, Mayo Foundation for Medical Education and Research, 3 Jan. 2018, www.mayoclinic.org/diseases-conditions/infectious-diseases/symptoms-causes/syc-20351173.

deadly.[4] The African region has the most concern for Malaria as it accounts for 92% of cases and 93% of deaths.[5] Malaria is caused by parasites that are transmitted to people through the bites of infected female Anopheles mosquitoes. Symptoms from the disease can stay dormant for about a year and typically present as fever, chills, headache, nausea and vomiting and muscle pain and fatigue.[6] The people who are at the most risk for malaria are pregnant women, travellers coming from areas without malaria and children under the age of 5. There is no vaccine or extremely effective cure for malaria. Most treatments used are active against the parasite in the blood including: Chloroquine, Atovaquone-proguanil (Malarone®), Artemether-lumefantrine (Coartem®), Mefloquine, Quinine and Doxycycline (used in combination with quinine).[7] However, antimalarial drug resistance is very common and many malaria drugs are not very efficient and they need to be distributed with caution. There are still no major advancements on a vaccine for malaria.

The mosquito that is of the huge concern right now is the aedes mosquito. The different types of aedes mosquitoes can spread yellow fever, dengue fever, chikungunya and zika. Yellow fever is known for its large epidemics when the disease meets a large population. Typically, yellow fever only resonates in the body for 3-6 days with no symptoms or minor symptoms. However, some people begin a toxic phase 24 hours after the minor symptoms resolve. Half of the people that go through the toxic phase die within 7-10 days.[8] Thankfully, yellow fever is one of the few vector borne diseases with an extremely effective vaccine. The yellow fever vaccine is 80-90 percent effective for 99 percent of the population after one dose.[9] The reason why yellow

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[4] "Fact Sheet about Malaria." *World Health Organization*, World Health Organization, 2019, www.who.int/news-room/fact-sheets/detail/malaria.

[5] "Fact Sheet about Malaria." *World Health Organization*, World Health Organization, 2019, www.who.int/news-room/fact-sheets/detail/malaria.

[6] "Malaria." *Mayo Clinic*, Mayo Foundation for Medical Education and Research, 13 Dec. 2018, www.mayoclinic.org/diseases-conditions/malaria/symptoms-causes/syc-20351184.

[7] "CDC - Malaria - Diagnosis & Treatment (United States) - Treatment (U.S.)." *Centers for Disease Control and Prevention*, Centers for Disease Control and Prevention, 2019, www.cdc.gov/malaria/diagnosis_treatment/treatment.html.

[8] "Yellow Fever." *World Health Organization*, World Health Organization, www.who.int/news-room/fact-sheets/detail/yellow-fever.

[9] "Yellow Fever." *World Health Organization*, World Health Organization, www.who.int/news-room/fact-sheets/detail/yellow-fever.

fever is still an issue for countries is the lack of access to vaccinations. Dengue is the fastest growing vector borne disease in the world. Dengue usually presents with flu like symptoms which can potentially be deadly. Serious symptoms occur 3-7 days after the first symptoms. Some extremely problematic symptoms include: severe abdominal pain, persistent vomiting, rapid breathing, bleeding gums, blood in vomit, fatigue and restlessness.[10] There is currently no treatments, cures or vaccines for dengue. Chikungunya causes mostly fever and joint pain. The joint pain is often very debilitating. It usually lasts for a few days or may be prolonged to weeks or even years. Therefore, the virus can cause acute, subacute or chronic disease.[11] Zika is another disease caused by aedes. Zika does not often show symptoms or if it does, they last for 2-7 days. However, zika becomes a greater concern when the person infected is pregnant. Zika can be transmitted from mother to fetus during pregnancy, resulting in microcephaly (smaller than normal head size) and other congenital malformations in the child.[12] These genetic abnormalities are collectively referred to as congenital Zika syndrome.

Different to many other vector borne diseases, lyme disease is spread by a black legged tick instead of a mosquito. For ticks to survive, they need to attach to a source. The ticks will attach onto either birds or rodents and become infected with the lyme disease bacteria (Borrelia burgdorferi). This bacteria is transferred to humans when the tick chooses the human as a host. Anywhere from 3 to 30 days after being bitten, a human can develop flu like symptoms. The most common indication of lyme disease is the redness of the skin surrounding the bite If these symptoms are not treated, the case of lyme disease can progress to being serious. In serious cases, lyme disease can lead to facial paralysis, heart disorders, neurological disorders, severe

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[10] "The Human." *World Health Organization*, World Health Organization, 3 Jan. 2017, www.who.int/denguecontrol/human/en/.

[11] "Chikungunya." *World Health Organization*, World Health Organization, 2017, www.who.int/news-room/fact-sheets/detail/chikungunya.

[12] "Zika Virus." *World Health Organization*, World Health Organization, 2018, www.who.int/news-room/fact-sheets/detail/zika-virus.

arthritis and even death. [13] Lyme disease is the vector borne disease best known to be found in areas with a cooler climate.

Due to the progression of technology in the medical field, the frequency of vector borne diseases, in theory, should be decreasing. However, vector borne diseases seem to be an increasing threat, even in developed countries. In the past three decades, the resurgence of vector-borne diseases has been apparent in many communities. This pattern coincides with human activity. Human activity that directly impacts vector-borne diseases include; anthropogenic climate change, demographic factors, and social activity. In the United States from 2004 through 2016, the number of reported cases increased from 27,388 to 96,075 a year.[14] The vector-borne diseases are also being spread further north in the United States and even up to Canada. As the summers are becoming warmer and summer travel is becoming more popular, the vectors are spreading like wildfire (see appendix figure 1.3) .

Despite vector-borne diseases being a global issue, there are very few solutions to the problem. Vaccines for vector borne diseases have had very little attention in the past as only a handful of vector borne diseases have vaccinations. Pesticides are the most common solution to vector borne diseases. However, pesticides give an extremely temporary solution. Due to mutations and genetic immunities, it is impossible to kill all vectors with a single insecticide.

Vector borne diseases have no cure and they continue to rapidly progress and spread. Many of the fatal diseases such as malaria are predicted to reach new territory by 2050 (see appendix, figure 3). Awareness needs to be raised and funds need to be prioritized towards this relatively new world issue. If suitable solutions are not found, the fifty percent of the population that is not affected by malaria and dengue will slowly decrease until it becomes a global health emergency.

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[13] Public Health Agency of Canada. "Symptoms of Lyme Disease." *Canada.ca*, 13 June 2017, www.canada.ca/en/public-health/services/diseases/lyme-disease/symptoms-lyme-disease.html.

[14] Redfield , Robert. "Vector-Borne Diseases More than Triple in US, CDC Says." *Healio*, SLACK Incorporated, 1 May 2018, www.healio.com/infectious-disease/emerging-diseases/news/online/%7Bd3de9226-dbcd-4125-a9df-9e2d5b768429%7D/vector-borne-diseases-more-than-triple-in-us-cdc-says.

Background

Some of the oldest types have vectors have been around for over 100 million years. In contrast, humans who have only been around between two-hundred thousand and four-hundred thousand years. Vector borne diseases likely predate human existence. However, knowledge on the subject has only been enlightened in recent years. Throughout history, there have been many rises and plummets in the cases and deaths of vector borne diseases.

One of the first documented cases of a vector borne disease was an epidemic of yellow fever from 1647-1650 where the disease was brought over from Africa to Barbados on an African slave ship. White settlers on the island had no immunity to the disease and six thousand of them died during an outbreak lasting several years.[15] Many other outbreaks of yellow fever and malaria became consistent throughout the seventeen and eighteen hundreds. In 1793, ships arrived from the West Indies to Philadelphia during a long hot summer. Infections spread and killed 5500 inhabitants with yellow fever before the winter temperatures eventually killed off the bugs.[16] Another large killing by yellow fever was in 1802 when the French sent 29,000 soldiers to Haiti and 6000 died due to the Europeans not being immune to the virus.[17]

Despite the continuous infestations of various vector borne illnesses, humans were still oblivious to the fact that the diseases were being caused directly by mosquitos and they were clueless to the cause of the death. Humans connected illness directly to dirt and waste and they reacted to these changes between 1830 and 1880. Europe spearheaded clean streets, clean water and proper drainage. Governments built drainage systems, sewers and soon paved roads. The new cleanliness in the western world did a great deal to eradicate vector borne diseases. Good

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[15] "Highlights of Vector-Borne Disease History." *WHO Malaria Fact Sheet | IVCC*, 2019, www.ivcc.com/saving-lives/how-vector-control-saves-lives/history-of-vector-control/highlights-of-vector-borne.

[16] "Highlights of Vector-Borne Disease History." *WHO Malaria Fact Sheet | IVCC*, 2019, www.ivcc.com/saving-lives/how-vector-control-saves-lives/history-of-vector-control/highlights-of-vector-borne.

[17]" Highlights of Vector-Borne Disease History." *WHO Malaria Fact Sheet | IVCC*, 2019, www.ivcc.com/saving-lives/how-vector-control-saves-lives/history-of-vector-control/highlights-of-vector-borne.

sanitation made it more challenging for the vector borne disease to spread as rapidly. In 1880, Memphis built a sanitation system, and the city never again suffered a yellow fever outbreak.[18] Humans started controlling the rise of vector borne diseases without any knowledge of the issue itself. Vector borne diseases no longer became a worldwide issue.

Humans finally realized that malaria, yellow fever and other fatal diseases were a result of vectors, primarily mosquitos. Ronald Ross was the first person to make this observation in 1897 and won a Nobel Prize for his efforts.[19] In India, he studied the lifecycle of the parasites of malaria in mosquitoes proving that they were connected. As soon as humans realized that bugs were killing them, they started killing bugs. They used military style approaches to try to eliminate them. In 1943, DDT (dichloro-diphenyl-trichloroethane), a strong pesticide, was invented and humans thought they had beat vector borne diseases.[20] People started overusing DDT and in various locations in the world, vectors became immune to the chemicals. It was also believed that DDT had no negative impacts until the release of Rachel Carson's famous book, "Silent Spring" in 1962. "Silent Spring" explained how once DDT entered a food chain it accumulated in the fatty tissues of various species and caused cancer and genetic damage.[21] From that point forward, DDT was either banned or strictly monitored in most countries.

Today vector borne diseases are once again a worldwide issue. A example of this is malaria. There was a huge resurgence of malaria in Asia in the late 1960's and early 1970's. Sri Lanka went from 17 reported cases in 1963, to 537,705 cases in 1969.[22] Malaria has spiralled out of control. Significant awareness has been raised to the cause and many treatment baths have

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[18] "Highlights of Vector-Borne Disease History." *WHO Malaria Fact Sheet | IVCC*, 2019, www.ivcc.com/saving-lives/how-vector-control-saves-lives/history-of-vector-control/highlights-of-vector-borne.

[19] Biographical. NobelPrize.org. Nobel Media AB 2019. Sat. 2 Mar 2019. <https://www.nobelprize.org/prizes/medicine/1902/ross/biographical/>

[20] "Highlights of Vector-Borne Disease History." *WHO Malaria Fact Sheet | IVCC*, 2019, www.ivcc.com/saving-lives/how-vector-control-saves-lives/history-of-vector-control/highlights-of-vector-borne.

[21] "The Story of Silent Spring." *NRDC*, 6 Apr. 2018, www.nrdc.org/stories/story-silent-spring.

[22] Gubler, Duane. "Resurgent Vector-Borne Diseases as a Global Health Problem - Volume 4, Number 3-September 1998 - Emerging Infectious Diseases Journal - CDC." *Centers for Disease Control and Prevention*, Centers for Disease Control and Prevention, 14 Dec. 2010, wwwnc.cdc.gov/eid/article/4/3/98-0326_article.

been attempted. However, despite the estimated 3.1 billion dollars dedicated to malaria control, it is estimated that nearly half the world's population is still at risk.[23]

Other mosquito borne diseases have very little funding and awareness compared to malaria. The aedes aegypti mosquito is one of the biggest threats as it is primarily responsible for transmitting Zika, dengue, chikungunya and yellow fever. [24] Dengue fever is the fastest growing vector borne disease. Like malaria, half the world's population is now at risk in over 100 countries for dengue.[25] (see appendix figure 2.1) The other concerning disease from aedes aegypti is yellow fever. In Africa in 2013, there were 84 000 to 170 000 severe cases and 29 000 to 60 000 deaths due to yellow fever. A significant awareness was raised for the zika virus in 2015 and 2016 when a huge breakout occurred in Brazil and many South American countries. The world became very concerned with the upcoming 2016 Olympics to be held in Brazil.

[23] "Fact Sheet about Malaria." *World Health Organization*, World Health Organization, 19 Nov. 2018, www.who.int/news-room/fact-sheets/detail/malaria.

[24] "Aedes Aegypti Mosquitoes." *World Mosquito Program*, www.eliminatedengue.com/our-research/aedes-aegypti.

[25] "Dengue and Severe Dengue." *World Health Organization*, World Health Organization, 13 Sept. 2018, www.who.int/en/news-room/fact-sheets/detail/dengue-and-severe-dengue.

Expert

As the awareness for vector borne diseases increases, so does the amount of experts on the subject. Most major universities have a department of infectious diseases and within that department, a tropical disease specialist as well. Many universities have vector borne diseases specialists. In recent years, there has been increased funding towards finding a solution for vector borne diseases, specifically malaria.

In 2015, one of the recipients of the Nobel Prize in Physiology was Tu Youyou. She was employed at the China Academy of Traditional Chinese Medicine in Beijing. This extremely prestigious award was given to her for her astonishing therapy findings that proved effective against malaria. Malaria, the world's most deadly vector borne disease presents common symptoms including extremely high fevers and chills. Youyou's treatment discovery came from a traditional Chinese treatment of using sweet wormwood to treat fevers. Tu Youyou managed to extract a substance called artemisinin, which can hold back the malaria parasite.[26] Artemisinin based drugs have made significant improvements in malaria studies and saved the lives of millions. In a translated interview, Tu Youyou speaks about her achievements saying:

> *So at the moment when we begin to research anti-malaria drug this old drug had already got drug resistance. As a result we worked very hard to find anti-malaria drug artemisinin and to save millions of lives. It shows that as a scientific worker we need innovation spirit to find new things.*[27]

This mindset and hard work is desperately needed to continue in the world to manage vector borne diseases. Tu Youyou's work has been very beneficial to society and has saved millions of lives.

At McMaster University, Martha Fulford is one of the most knowledgeable on vector borne diseases. She is the director of International Health and Tropical Diseases Clinic at Hamilton Health Sciences. She also works as an associate professor at McMaster University.

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[26] "The Nobel Prize in Physiology or Medicine 2015." *Nobelprize.org*, 2015, www.nobelprize.org/prizes/medicine/2015/tu/facts/.

[27] "The Nobel Prize in Physiology or Medicine 2015." *Nobelprize.org*, 2015, www.nobelprize.org/prizes/medicine/2015/tu/interview/.

She provides infectious disease consultants to both adults and children. She has a particular interest in travel related infections and in zoonoses.[28] In addition to her clinical work, Dr. Fulford is the Chief of Medicine for the McMaster University Medical Centre site and is the medical/clinical director of the McMaster Travel Clinic and of the Boris Clinic. She is educated globally on vector borne diseases and speaks on a worldly lense about the subject (see figure A for interview).

At the University of Queens, Gerald Evans is a knowledgeable expert on vector borne diseases. He is Chair of the Division of Infectious Diseases and a Professor in the Departments of Medicine, Biomedical & Molecular Sciences, and Pathology & Molecular Medicine at Queen's. He is also an attending physician in Infectious Diseases and Internal Medicine at Kingston General Hospital and the Hotel Dieu Hospital in Kingston, Ontario.[29] One of his interests is in drug optimization which will give insight into vector resistance to drugs and how to prevent this. Due to his current lyme disease studies he gives great indigent to vector borne diseases in Canada. (See figure B for interview)

[28] Electra Communications. "McMaster University Department of Medicine >> Infectious Diseases." *McMaster University Department of Medicine >> Division of Infectious Diseases >> Faculty Member Dr. Martha Fulford*, fhs.mcmaster.ca/medicine/infectious_diseases/faculty_member_fulford.htm.

[29] "Gerald Evans." *Queen's University School of Medicine* , deptmed.queensu.ca/people/gerald-evans.

The Role Of Control

Vector borne diseases have likely always existed and will likely continue to exist. However, there is a direct correlation between the actions of humans and the shift in the measure of vector borne diseases. Historically, humans have greatly decreased the amount of vectors by improving on sanitation and by developing insecticides such as DDT. Recent human activity such as climate change, rapid civilization growth and social factors have been increasing the spread of vector borne diseases. Humans have the control to both increase and decrease vector borne diseases. However, immediate preventative action is necessary for a long term positive outcome.

One of the primary ways humans have been directly increasing vector borne diseases has been through anthropogenic climate change. Anthropogenic climate change is caused by human activity instead of by the natural processes of the planet. It is concluded by scientific experts all over the world that there is more than a 95 percent probability that human activities over the past 50 years have significantly warmed our planet.[30] A change of temperature for vector borne diseases can result in multiple changes. These changes include survival rates, vector population growth or decay, feeding behaviour, susceptibility to pathogens, seasonal vector activity and seasonally pathogen transmission.[31] Vectors are cold blooded species and particularly thrive in warm environments. Warmer environments will increase vector survival rate, lengthen breeding season, increase pathogens and will increase the vector's feeding season. This has already progressed into an issue as the IPPC (Intergovernmental Panel on Climate Change) has reported that climate change has already altered the the distribution of some vector borne diseases. This is based on the evidence of ticks extending their range to Sweden, Canada and higher altitudes in

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[30] "Climate Change Causes: A Blanket around the Earth." *NASA*, NASA, 5 Feb. 2019, climate.nasa.gov/causes/.

[31] Hunter, P.R. "Climate Change and Waterborne and Vector‐Borne Disease." *The Canadian Journal of Chemical Engineering*, Wiley-Blackwell, 8 Apr. 2003, onlinelibrary.wiley.com/doi/full/10.1046/j.1365-2672.94.s1.5.x.

Czech Republic.[32] This will only progress to become more of an issue. By 2100, it is estimated that average global temperatures will have risen by 1.0 to 3.5 °C, creating an even more habitable environment for vectors. Anthropogenic climate change has already begun to affect the spread of vectors and will continue to do so if not considered a priority.

Humans are also directly contributing to the rise of vector borne diseases by their expansive civilization growth . Infectious diseases started to become a substantial issue when humans started to live in large groups. Incidentally, the ideal place for infectious disease to spread is among large groups in close quarters, especially in unsanitary conditions. In continents such as Africa and Asia, humans are starting to urbanize more. However, poverty associated with rapid population growth leads to concentrations of people without the necessary infrastructure for the safe storage and distribution of water and drainage of wastewater.[33] Urban areas increase and foster the breeding of vectors and many governments have not been able to keep up with the high demand of housing. In many countries where vector borne diseases were already an issue, the spread of disease is becoming more prominent in urban areas. One in eight people live in slums, adding up to a total of around a billion people living in slum conditions today.[34] Slums consist of housing made with unfit materials with no supporting services. They are traditionally known as being dirty and unsanitary and are becoming more common. People who used to live in rural areas are flocking to urban areas. The closer humans move together, the faster diseases will spread. The more unsanitary the civilizations are, the more habitats (like greater areas of unclean water), will be available to vectors. The World Health Organization encourages governments to integrate disease control programs, including less dependence on pesticides; encouraging changes in human behavior; disseminating health messages; community

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[32] "Climate Change and Vector-Borne Disease." *The Water Cycle | UCAR Center for Science Education*, scied.ucar.edu/longcontent/climate-change-and-vector-borne-disease.

[33] Knudsen, A B, and R Slooff. "Vector-Borne Disease Problems in Rapid Urbanization: New Approaches to Vector Control." *Current Neurology and Neuroscience Reports.*, U.S. National Library of Medicine, 1992, www.ncbi.nlm.nih.gov/pubmed/1568273.

[34] "Slum Almanac 2015-2016." *UN Habitat* , UN-Habitat., 19 Oct. 2016, unhabitat.org/slum-almanac-2015-2016/.

participation, particularly the youth; mobilization of human and financial resources; and proper urban development to gain control of the situation.[35]

According to the 2015 statistics released by the United Nations World Tourism Organization (UNWTO), 1.184 billion people travelled outside of their country for at least one night.[36] The frequent travel in today's society gives the perfect opportunity for vectors to also travel. The authors write in "*PLoS Neglected Tropical Diseases*" about how insects that transport disease, such as mosquitoes, have been introduced via airlines to geographic areas where they didn't previously live. [37] For bags and cargo, there is the UN's International Health Regulations in place for insect-elimination, or "disinsection" the spraying of luggage with insecticides.[38] However, most of the spreading comes from humans travelling with the diseases. They can bring vector borne diseases to their travel destinations or back to their homeland. An example of this was shared in a study recorded in the New England Journal of medicine. The study was conducted in 2007 where chikungunya was diagnosed in an "unprecedentedly" large number of people returning to Europe and the United States from islands in the Indian Ocean where a 2006 outbreak occurred. The authors noted that the "*chikungunya outbreak is an example of the abrupt expression of vector-borne diseases in the global village.*"[39] It is essential to prepare humans for travel in high areas of vector borne diseases. Without this preparation and control, diseases will continue to spread as humans travel.

Humans are controlling the spread of vector borne diseases. It is imperative for them to be mindful and attempt to reduce their carbon footprint, settle down into civilizations appropriately and travel with caution. Vector borne diseases is not a highly advertised problem

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[35] Knudsen, A B, and R Slooff. "Vector-Borne Disease Problems in Rapid Urbanization: New Approaches to Vector Control." *Current Neurology and Neuroscience Reports.*, U.S. National Library of Medicine, 1992, www.ncbi.nlm.nih.gov/pubmed/1568273.

[36] "UNWTO: More International Tourists than Ever in 2015." *CNN*, Cable News Network, 20 Jan. 2016, www.cnn.com/travel/article/international-tourists-2015/index.html.

[37] Crist, Carolyn. "Mosquitoes Less Likely than People to Spread Disease via Air Travel." *Reuters*, Thomson Reuters, 18 July 2017, www.reuters.com/article/us-health-mosquitoes-disease-transmissio-idUSKBN1A31Y4.

[38] Crist, Carolyn. "Mosquitoes Less Likely than People to Spread Disease via Air Travel." *Reuters*, Thomson Reuters, 18 July 2017, www.reuters.com/article/us-health-mosquitoes-disease-transmissio-idUSKBN1A31Y4.

[39] Krisberg, Kim. "Vector-Borne Diseases Growing as Threats to U.S. Public Health: Climate Change, Travel Linked to Illness." *The Nation's Health*, American Public Health Association, 1 Sept. 2010, thenationshealth.aphapublications.org/content/40/7/1.2.

but people need to be concerned as vectors are one of the top killers of the world. Technology needs to continue to advance to find solutions instead of creating new problems.

International Organizations

There is no cure for many vector borne diseases. Many organizations have the common goal of either finding a solution or temporarily finding protection for people at risk of obtaining vector borne diseases.

The largest organization dealing with vector borne diseases is the World Health Organization (WHO). WHO is in partnership with the United Nations system in charge of addressing global health issues. WHO has created The *Global Vector Control Response (GVCR) 2017–2030* approved by the World Health Assembly (2017).[40] This is intended to provide support to countries attempting to improve vector control. It is essential for many areas of the world to prevent outbreaks and then learn to deal with them when they occur. One of the most effective preventative strategy WHO has been enforcing is bed nets to keep bugs away from humans as they sleep. It is the most long term solution as bed nets last from 2 to 3 years. Indoor residential spraying is needed by at least 80% of houses with a targeted maximum impact for 3 to 6 months.[41] This however is only a temporary and expensive solution. The longer lasting spray contains DDT which is harmful and has very strict limitations to it. Other potential solutions WHO have been working on include: outdoor spraying, addition of chemicals to water, genetic control, waste management and housing modifications. They are also suggesting improvements like personal protection, limited medicine and food safety for travellers.

A smaller global organization is the World Mosquito Program (WMP), previously known as Eliminate Dengue. Currently focussing their efforts in twelve countries, the WMP is trying to prevent diseases transmitted by the *Aedes aegypti* mosquito, including Zika, chikungunya and yellow fever. They use self sustaining methods that do not pose risk to existing ecosystems and has the potential to transform the global fight against life-threatening viral diseases.[42] They are utilizing *Wolbachia* which naturally occurs in up to 60% of all insect species. It is not found in

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[40] "Vector-Borne Diseases." *World Health Organization*, World Health Organization, 31 Oct. 2017, www.who.int/en/news-room/fact-sheets/detail/vector-borne-diseases.

[41] "A Global Brief on Vector-Borne Diseases." *World Health Organization*, 2014, apps.who.int/iris/bitstream/handle/10665/111008/WHO_DCO_WHD_2014.1_eng.pdf?sequence=1.

[42] "Eliminate Dengue - Our Challenge." *World Mosquito Program*, www.eliminatedengue.com/program.

the Aedes aegypti mosquito and when mosquitoes carry Wolbachia, they have a reduced ability to transmit the diseases of concern.[43] This is being done through controlled release of Wolbachia in areas where the aedes aegypti mosquito is a concern.

The United States of America has a very extensive program called the Centers for the Disease Control and Prevention (CDC). The CDC focuses on educating the public and putting action plans into place. They have broken up their mission into what the federal government, state and local government, universities/companies and the general public can do to help. Some of their ideas include educating the public, putting specific health centers into place and developing tests and vaccinations. The United States is taking this issue with the utmost seriousness as vector disease cases have tripled in 13 years[44] (see appendix figure 4).

Canada has its own version of the CDC. It is called the G Magnotta Foundation. It is a non profit organization for vector borne disease run out of the University of Guelph. It deals with all vector borne diseases but it is primarily working with lyme disease. Lyme disease is a tick borne disease and is the most prominent vector borne disease in Canada. On the Foundation website it stated both the good news and the bad news on the fight against lyme disease. The good news revealed that they know what it is, how to prevent it and how to treat it in early stages. The bad news divulged that Canada does not realize the extent of the rise of vector borne diseases and the Canadian technology to counteract lyme disease is very outdated, unreliable and at times, non-existent. One of their current research strategies they are working on is analyzing the complete collection of genetic material and proteins of Borrelia burgdorferi (where lyme disease originates from.)[45] Doing this will provide clues about pathogenic mechanism. The G Magnotta Foundation is named after a Canadian who passed away from lyme disease and they remain determined to fight for a cure.

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[43] "Our Research." *World Mosquito Program*, www.eliminatedengue.com/our-research.

[44] "Illnesses on the Rise | VitalSigns | CDC." *Centers for Disease Control and Prevention*, Centers for Disease Control and Prevention, 2018, www.cdc.gov/vitalsigns/vector-borne/index.html#anchor_1508961789.

[45] "Our Research." *G. Magnotta Foundation*, www.gmagnottafoundation.com/our-research.

There are even more international organizations working with various countries for a common, dire purpose. Organizations are attempting to identify any possibilities, any solutions, for the vector borne crisis. Establishing these organizations are some of the primary steps to helping resolve this rapidly growing concern.

Case Studies

Case study 1- India

India, a South Asian country is the seventh largest country geographically and the second largest in population. Based on a United Nation's report, India has a population of about 1.37 billion.[46] One out of six people in the world could conceivably live in India. The large country is known to be a hot, tropical country. In most areas, the summers are brutally hot, reaching over forty-five degrees while the winters rarely drop below twelve degrees.[47] The large population is known for its deep culture and diverse nation as is home to religions such as Hinduism, Islam, Sikhism, Christianity, Buddhism, Jainism, Zoroastrianism, Judaism and the Bahá'í Faith.[48] India is situated in an ideal trade location. It geographically located near highly populated trade partners Bangladesh, Pakistan and China. In 2018, India shipped $323.1 billion (US dollars) worth of goods around the globe majorly including mineral fuels; oil, gems, precious metals and machinery including computers.[49] Despite the various exports, India is considered one of the poorest countries on the world. Two-thirds of people in India live in poverty: 68.8% of the Indian population lives on less than $2 a day.[50]

Information regarding the climate, large population and common poverty provides insight into why vector borne diseases are an issue in India. There were approximately one million malaria cases in 2010 in India. "We have seen significant increase in the number of people falling ill due to these vector-borne diseases. This year in India, more than 300,000 cases of malaria and 80,000 cases cases of dengue were reported," said Bajaj Allianz General Insurance

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[46] "India Population 2019." *India Population 2019 (Demographics, Maps, Graphs)*, 2019, worldpopulationreview.com/countries/india-population/.

[47] Weatheronline.co.uk. "India." *WeatherOnline*, www.weatheronline.co.uk/reports/climate/India.htm.

[48] "Indian Religions." *Indian Religions - Religions In India - Religions Of India - Indian Religion -Major Religions Of India*, www.culturalindia.net/indian-religions/.

[49] "India's Top 10 Exports." *World's Top Exports*, 8 Mar. 2019, www.worldstopexports.com/indias-top-10-exports/.

[50] "Poverty in India: Facts and Figures on the Daily Struggle for Survival." *SOS Children's Villages Canada*, www.soschildrensvillages.ca/news/poverty-in-india-602.

MD & CEO Tapan Singhel. [51] Determinants of these increases include: water, housing, climate, poverty, air travel and health systems.

India is the ideal place for vector borne diseases to spread and for the number of vectors to increase. Water is often the source for infection and breeding as inadequate sanitation and exposure to human faeces are linked to the transmission of vector borne diseases.[52] In India, lack of proper drainage system, water stagnation and vast vegetation cover provides the favourable ambience for mosquito growth and proliferation.[53] Climate is also a major role in creating a habitable environment for vectors. India's extreme weather accounted for 25% of accidental deaths in India between 2001 and 2014, according to one study. Within this, lightning and precipitation accounted for over 60% of weather-related deaths, while heat waves were responsible for 20%.[54] The drastic heat waves and the pools of water that lingered after storms provide an ideal space for vectors to thrive.

The housing conditions of India also increase the spread in vector borne diseases. In India's city Bihar, housing material, in-house granaries and the presence of 18 bamboo trees near houses in new settlements were risk factors of kala-azar; a vector borne disease spread by sand flies.[55] Unplanned urbanization with unsanitary conditions is common to poor countries with growing populations such as India.

Lastly, India's poor health care system strongly promotes the spread of vector borne diseases. India's health system is often not accessible to the poor becomes a financial burden as 75 percent of health spending is out of pocket.[56] Many families will not get diseases treated early

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[51] Tnn. "Health Cover for Only Vector-Borne Diseases - Times of India." *The Times of India*, Business, 15 Jan. 2019, timesofindia.indiatimes.com/business/india-business/health-cover-for-only-vector-borne-diseases/articleshow/67549470.cms.

[52] WHO Country Office for India (2014). Vector-borne diseases in India: An analysis from a health systems approach. New Delhi.

[53] Bharati, Minu & Saha, Dhiraj. (2017). Mosquito Borne Diseases: Current and Control Approach in India Vector-Borne Diseases & Treatment

[54] "What Would a 2°C Rise in Global Temperature Mean for India?" *The Weather Channel*, weather.com/en-IN/india/pollution/news/2018-10-03-what-would-a-2degc-rise-global-temperature-mean-india.

[55] WHO Country Office for India (2014). Vector-borne diseases in India: An analysis from a health systems approach. New Delhi.

[56]WHO Country Office for India (2014). Vector-borne diseases in India: An analysis from a health systems approach. New Delhi.

on which leads to high death rates. Poor healthcare also disadvantages citizens from an early age from not having access to vaccines or medicine.

In India, the majority of vector borne diseases are caused from one of the four common mosquitos; Anopheles, Aedes, Culex and Mansonia. Each of these cause different diseases. The Anopheles is responsible for malaria, Aedes is responsible for majorly dengue and chikungunya, Culex and Mansonia both transmit filaria and Japanese encephalitis.[57]

Around 95% of the Indian population lives in areas at risk of malaria. Therefore, more than 100 million blood slides are examined annually with around one million cases of malaria reported in the country.[58] India nearly had malaria eradicated in the 1960's but since then it has re-emerged and causes over 1,000 reported deaths every year.[59] Not only does malaria have a large mortality impact, it also significantly affects India's economy. It diminishes the agricultural production as the anopheles mosquitoes breed at the same time as harvest season, underlying worker's capabilities. In India, malaria mortality primarily occurs in the economically productive age group of 15-44 years which has ultimately resulted in the country's economic burden of around US$ 1940 million due to malaria.[60] To save the country from thousands of deaths and millions of wasted dollars, it is imperative for India to advance a malaria control solution.

Denage is the fastest growing and most threatening vector borne disease. Denage was introduced in the 1950's but has predominantly emerged in the past two decades. (see figure 3) In India, a epidemic was reported in 2012, with over 50 000 cases and about 250 deaths.[61] India has continued to have major epidemics in 2016 and 2017. Many patients were hospitalized for long periods of times because of dengue. Hospital services in India are also quite expensive as

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[57] Bharati, Minu & Saha, Dhiraj. (2017). Mosquito Borne Diseases: Current and Control Approach in India Vector-Borne Diseases & Treatment

[58] WHO Country Office for India (2014). Vector-borne diseases in India: An analysis from a health systems approach. New Delhi.

[59] Bharati, Minu & Saha, Dhiraj. (2017). Mosquito Borne Diseases: Current and Control Approach in India Vector-Borne Diseases & Treatment

[60] Bharati, Minu & Saha, Dhiraj. (2017). Mosquito Borne Diseases: Current and Control Approach in India Vector-Borne Diseases & Treatment

[61] WHO Country Office for India (2014). Vector-borne diseases in India: An analysis from a health systems approach. New Delhi.

the average cost of treatment per hospitalised dengue patient was estimated to be US$432.2.[62] The cost on the economy due to dengue was estimated to be US$27.4 million and from the private health sector it is estimated to be 4 times higher.[63]

Aedes mosquitoes also spreads chikungunya. There have been many outbreaks of chikungunya since the 1960s but there was a disappearance of the disease for many years. Scientists suspect that the recurrence of the disease is due to recent travel to India. A major epidemic of chikungunya was reported in 2008 with about 1.3 million cases in 213 districts in 15 states.[64] Chikungunya has the symptoms of disabling the body through severe joint pain called arthralgia which affects many citizens ability to work and contribute to society.

Filaria and Japanese encephalitis are both common vector borne diseases in India spread by Culex and Mansonia mosquitoes. Over 600 million people in India are at risk of infection from Filaria or Lymphatic filariasis and about 40 million are infected every year which is one-third of the global cases.[65] Filaria targets the lymphatic system. It is a poor disease as it is directly related to inadequate sanitation. The annual economic loss due to filariasis in India is US$ 1 billion. Japanese encephalitis (JE) first came to India in about 1955. Annually 35000-50000 cases of JE infection are reported, of which 30-50 % of individuals face neurological infection whereas 20-40% die.[66] JE mosquitoes commonly assume farmland habitat, which takes a toll on workers in the agricultural field.

Due to the tremendous economic and mortality effects from vector borne diseases, India is investigating many possible solutions. These possible solutions are divided into two categories, disease control and prevention and vector control.

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[62] Bharati, Minu & Saha, Dhiraj. (2017). Mosquito Borne Diseases: Current and Control Approach in India Vector-Borne Diseases & Treatment

[63] Bharati, Minu & Saha, Dhiraj. (2017). Mosquito Borne Diseases: Current and Control Approach in India Vector-Borne Diseases & Treatment

[64] WHO Country Office for India (2014). Vector-borne diseases in India: An analysis from a health systems approach. New Delhi.

[65] Bharati, Minu & Saha, Dhiraj. (2017). Mosquito Borne Diseases: Current and Control Approach in India Vector-Borne Diseases & Treatment

[66] Bharati, Minu & Saha, Dhiraj. (2017). Mosquito Borne Diseases: Current and Control Approach in India Vector-Borne Diseases & Treatment

When you squeeze out toothpaste from a bottle, it is impossible to get the toothpaste back in. However if you leave the cap on, the toothpaste never escapes. This is a metaphor for the prevention of vector borne diseases. Preventable measures and early diagnosis are key to controlling the spread. Vaccinations are a great strategy to prevent vector borne diseases. Unfortunately, there is only one reliable vaccine for a major vector diseases in India. The vaccine for Japanese encephalitis has been integrated in endemic areas as part of the general immunization schedule. The JE vaccination was started in India in 2006. Large campaigns were introduced between the years of 2006-2009. Until 2015, 155 JE endemic districts have been covered under Japanese encephalitis campaign vaccination and campaigns for adults then started to be conducted.[67] Malaria does not have a vaccine in place so India's efforts to control it include: Drug Distribution Centres (DDCs) and Fever Treatment Depots (FTDs) created in the rural areas for providing easy access to antimalarial drugs.[68] Chloroquine is the most effective anti-malarial drug. However, some cases have become resistant and other drugs need to be used as substitution. For filariasis, the government of India is participating in an annual mass drug administration with single dose of DEC (Diethylcarbamazine citrate) and Albendazole to prevent infestation. However, diseases like dengue and chikungunya have no preventative drugs.

As a result of very few medical advancements on the vector borne diseases, vector control remains to be the primary solution. Personal vector control in India is now frequently used including mosquito repellent creams and coils, proper covering of exposed human parts, and screening of house with wire meshes.[69] Additionally, chemical control includes indoor spraying and use of larvaides. DDT was previously used in India until it was deemed harmful and no longer effective. For mosquito larval control, temephos is the most preferred larvicide, also recommended by both WHO and National Vector Borne Disease Control Programme

[67] WHO Country Office for India (2014). Vector-borne diseases in India: An analysis from a health systems approach. New Delhi.

[68] WHO Country Office for India (2014). Vector-borne diseases in India: An analysis from a health systems approach. New Delhi.

[69] WHO Country Office for India (2014). Vector-borne diseases in India: An analysis from a health systems approach. New Delhi.

(NVBDCP).[70] A few other strategies include trying to eliminate favourable habitats for vectors and educating the community on what to watch for and look out for.

[70] WHO Country Office for India (2014). Vector-borne diseases in India: An analysis from a health systems approach. New Delhi.

Case Study 2- Brazil

Brazil is the largest country in South America. It is the fifth largest country in both land size and population. Brazil has an average of 1.77 births per woman, and the 2019 population is approximately 212.39 million.[71] Brazil has a tropical climate as temperatures rarely drop below 20 degrees. Brazil borders on the ocean and is a relatively flat country consisting of plateaus and plains which make it ideal for farming. Some of the main exports of Brazil include: soybeans , iron ore, crude petroleum, raw sugar and cars.[72] The Brazilian Institute of Geography and Statistics (IBGE) states that more than fifty million Brazilians, nearly 25 percent of the population, live below the poverty line and have family incomes of $387.07 per month – approximately US $5.50 a day.[73]

Brazil has the ideal climate and landscape for vector borne diseases to thrive. The hot temperatures and farmland attract many bugs. The aedes mosquito is the most problematic vector in Brazil. The aedes mosquito transmits zika, dengue and chikungunya which are all present in Brazil. These diseases occur in Brazil due to deforestation, poor sanitation and the introduction of new viruses like Chikungunya and Zika through travel.

> Land use change is coming up as a significant driver of disease events, particularly from wildlife, this is a wake-up call. Deforestation and land conversion for agriculture is one of the biggest drivers of pandemics. We need to get on the case very quickly." Peter Daszak the president of Eo health alliance.[74]

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[71] "Brazil Population 2019." Brazil Population 2019 (Demographics, Maps, Graphs), 2019, worldpopulationreview.com/countries/brazil-population/.

[72] "Brazil." *OEC - Brazil (BRA) Exports, Imports, and Trade Partners*, 2017, atlas.media.mit.edu/en/profile/country/bra/.

[73] Forte, Jay. "More Than 50 Million Brazilians Living Below Poverty Line." *The Rio Times*, 16 Dec. 2017, riotimesonline.com/brazil-news/rio-politics/more-than-25-million-brazilians-living-below-poverty-line/.

[74] Morrison, Jim. "Did Deforestation Contribute to Zika's Spread?" *Smithsonian.com*, Smithsonian Institution, 8 June 2016, www.smithsonianmag.com/science-nature/did-deforestation-contribute-zikas-spread-180959305/.

Brazil has an extremely high deforestation rate. Between August 2017 and July 2018, 7,900 sq kms were deforested.[75] Deforestation leads to more sun exposure, creating hotter temperatures, and streams being redirected thus causing sitting pools of water and the growing of shrubberies. These conditions are ideal for vector habitats. Cutting four percent of a forest in Brazil, was associated with a nearly 50 percent increase in human malaria cases, in a 2010 study.[76]

The lack of sanitation in Brazil also has a direct correlation to vector borne diseases. Brazil's government estimates 40 percent of homes in the country are not connected to a sewage system. Despite this, the budget for improving basic sanitation in Brazil was cut by 70 percent in 2016.[77] Areas without sewage have dirty water collecting in pools which is where vectors breed. One in five Rio Janeiro residents live in favelas, which are high-density areas that lack basic sanitation.[78] In favelas, with the unsanitary close quarters, vector borne diseases spread at a rapid pace. As time passes, more vector borne diseases are being introduced to Brazil through human travel. It is estimated that Chikungunya arrived between 2012 and 2014 from east, central or south Africa.[79] Scientists have also traced the spread of zika by a traveller from French Polynesia. Molecular studies showed that viruses from the two countries were virtually identical, and the disease did not come from African lineage.[80] The disease was likely brought during the August 2014 World Sprint Championship canoe race, held in Rio de Janeiro.

> If I had to make the choice today, I wouldn't go to the Olympics, The zika virus is definitely a concern to me. I'm obviously keeping an eye on what's going on in the news.

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[75] Phillips, Dom. "Brazil Records Worst Annual Deforestation for a Decade." *The Guardian*, Guardian News and Media, 24 Nov. 2018, www.theguardian.com/environment/2018/nov/24/brazil-records-worst-annual-deforestation-for-a-decade.

[76] Morrison, Jim. "Did Deforestation Contribute to Zika's Spread?" *Smithsonian.com*, Smithsonian Institution, 8 June 2016, www.smithsonianmag.com/science-nature/did-deforestation-contribute-zikas-spread-180959305/.

[77] "The Bigger Problems behind Brazil's Recent Disease Outbreaks." *Public Radio International*, 2016, www.pri.org/stories/2016-02-26/bigger-problems-behind-brazils-recent-disease-outbreaks.

[78] "The Bigger Problems behind Brazil's Recent Disease Outbreaks." *Public Radio International*, 2016, www.pri.org/stories/2016-02-26/bigger-problems-behind-brazils-recent-disease-outbreaks.

[79] Columbia University's Mailman School of Public Health. "Study traces the origins of Chikungunya in Brazil." ScienceDaily. ScienceDaily, 26 February 2019. <www.sciencedaily.com/releases/2019/02/190226091554.htm>.

[80] "One Year into the Zika Outbreak: How an Obscure Disease Became a Global Health Emergency." *World Health Organization*, World Health Organization, 13 June 2016, www.who.int/emergencies/zika-virus/articles/one-year-outbreak/en/index2.html.

> I do know that it's spreading and they don't really have a vaccination to treat it, so it's definitely worrisome - Hope Solo, American soccer player[81].

The world really started to take notice in vector borne diseases during the Rio 2016 Summer Olympics. Prior to the olympics, Brazil was having a zika epidemic. Zika is a vector borne disease that comes from the aedes mosquito. Zika can also be transmitted through sexual intercourse and from mother-to-child during pregnancy. Zika is not typically a deadly disease but it can have serious implications when a pregnant woman is affected as it can lead to microcephaly and other neurological impairments to the child. In September 2015, there were many reports of children being born with microcephaly in areas that the zika disease occupied. The Brazil Ministry of Health (MoH) spotted a correlation between the two diseases. On November 12, 2015, the Ministry of Health declared a national public health emergency in Brazil and on February 1, 2016, the World Health Organization (WHO) declared zika a public health emergency of international concern.[82] Approximately 200, 000 cases were notified by the end on 2016. The zika virus has significantly harmed Brazil's economy. The 2016 Olympics really brought the zika virus to the forefront . Funding for dengue outbreak prevention registered an increase of 32% between 2012 and 2015.[83] Even more money will need to prioritized toward zika research which is certainly challenging for a country in debt. A loss in productivity will also occur as a result of the many of the microcephaly cases. Children born with the impaired cognitive and physical development may not have the ability to achieve their full cognitive potential.[84]

As much as zika was a large epidemic in 2015, chikungunya and dengue are diseases causing ongoing concerns. Chikungunya had the first major epidemic in 2014. Since then, numbers have continued to increasingly grow. 60% of the time, Chikungunya can come with

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[81] Pearl, Diana. "'I Don't Care About No Stupid Bugs' and What More Olympians Are Saying About the Zika Virus." *PEOPLE.com*, 2016, people.com/celebrity/rio-olympics-2016-zika-quotes-from-athletes/.

[82] Lowe, R.; Barcellos, C.; Brasil, P.; Cruz, O.G.; Honório, N.A.; Kuper, H.; Carvalho, M.S. The Zika Virus Epidemic in Brazil: From Discovery to Future Implications. *Int. J. Environ. Res. Public Health* **2018**, *15*, 96.

[83] "The Potential Economic Impact of the Zika Virus." *IVAC JHU The Potential Economic Impact of the Zika Virus Comments*, www.jhsph.edu/ivac/2016/03/16/the-potential-economic-impact-of-the-zika-virus/.

[84] The Potential Economic Impact of the Zika Virus." *IVAC JHU The Potential Economic Impact of the Zika Virus Comments*, www.jhsph.edu/ivac/2016/03/16/the-potential-economic-impact-of-the-zika-virus/.

arthralgia, arthritis, myalgia, and fatigue, lasting up to 3 years**.** The most severely affected individuals are likely to be referred to rheumatologists who try nonsteroidal antiinflammatory drugs, glucocorticoids, disease-modifying antirheumatic drugs and biological drugs.[85] Brazil has just over 2000 rheumatologists, a limited number to manage nearly half a million reported chikungunya arthritis cases in the past 3 years.[86] There has been a slight bit of interest on vaccine development, but commercialization seems unlikely in the near future. Dengue is a serious concern in Brazil as the number of endemics has skyrocketed in the last 15 years. Dengue was not present in Brazil for 30 years before it made a resurgence in the year 1981. Brazil registered an astonishing record of 1.65 million dengue cases in 2015 alone.[87]

Brazil is looking to implement more strategies to control vector borne diseases. For dengue specifically, "Dengue tents" have been set up to treat patients in high-risk areas within the city.[88] Education is key to eliminating vector borne diseases. 2,500 health officials have been sent door-to-door to educate residents on preventive measures. Some of these include filling potted plants with sand, keeping containers dry and swimming pools covered, as well as placing mosquito nets over open water tanks.[89] Brazil has put in place many vector control strategies primarily for the aedes mosquito. They have created a Partnership with Ministry of Environment and private sectors to collect and dispose of tires eliminating ideal breeding spots. Brazil also has a monitoring system for insecticide resistance and is managing insecticides in areas with resistance.

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[85] Amaral, J. Kennedy, and Robert T. Schoen. "Chikungunya in Brazil: Rheumatologists on the Front Line." *The Journal of Rheumatology*, The Journal of Rheumatology, 1 Oct. 2018, www.jrheum.org/content/45/10/1491.

[86] Amaral, J. Kennedy, and Robert T. Schoen. "Chikungunya in Brazil: Rheumatologists on the Front Line." *The Journal of Rheumatology*, The Journal of Rheumatology, 1 Oct. 2018, www.jrheum.org/content/45/10/1491.

[87] Amaral, J. Kennedy, and Robert T. Schoen. "Chikungunya in Brazil: Rheumatologists on the Front Line." *The Journal of Rheumatology*, The Journal of Rheumatology, 1 Oct. 2018, www.jrheum.org/content/45/10/1491.

[88] Berdjis , Noushin. " Dengue Epidemic in Brazil." *Dengue Epidemic in Brazil | HealthMap*, 2015, www.diseasedaily.org/diseasedaily/article/dengue-epidemic-brazil-51315.

[89] Berdjis , Noushin. " Dengue Epidemic in Brazil." *Dengue Epidemic in Brazil | HealthMap*, 2015, www.diseasedaily.org/diseasedaily/article/dengue-epidemic-brazil-51315.

Case Study 3- Uganda

Uganda is a landlocked country in Africa bordering the Democratic Republic of the Congo (DRC), Kenya, Rwanda, Sudan and Tanzania. It is on the edge of the equator giving it a warm tropical climate of between 25- 29 degrees celsius on average. [90] Uganda has an abundance of fresh water and it is home to the second largest freshwater lake in the world, Lake Victoria. The scenery of the country is composed of mountainous regions, tropical forests, rolling savannahs, plains and many farm lands and plantations. The top exports of Uganda include: coffee, gold, dried legumes, fish fillets and cocoa beans.[91] Uganda has one of the largest birth rates in the world with an average of 5.59 children per woman in 2016.[92] The result in an extremely young population. In Uganda, 19.7 percent of people are below the poverty line; this number has actually reduced in recent years due to the growth of agricultural jobs.

A 2006 Ministry of Health study of neglected diseases and their control in Uganda identified vector-borne diseases as part of a group of the most neglected diseases in the country. [93] Breeding grounds for vector borne diseases have been produced as wet marshy areas have become urbanized. The inclined or mountainous parts of Uganda that never used to be affected by vectors are now experiencing outbreaks. A large part of Uganda's crisis on vectors is due to climate change. "Rain has become my enemy. When it rains, my heart sinks," says Jane, an entrepreneur in Uganda.[94] Heavy rain and flooding that coincides with it, provides pools of water, the perfect places for vectors to breed and inhabit. Droughts also attract vectors to barrels of water used by multiple people. Land changes due to agriculture can also alter local climate changes. In a study conducted at high altitudes in Uganda, it was clear, that areas in which

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[90] "Uganda." *World Travel Guide*, www.worldtravelguide.net/guides/africa/uganda/weather-climate-geography/.

[91] "Uganda." *OEC - Uganda (UGA) Exports, Imports, and Trade Partners*, atlas.media.mit.edu/en/profile/country/uga/.

[92] "Fertility Rate, Total (Births per Woman)." *Data*, 2016, data.worldbank.org/indicator/SP.DYN.TFRT.IN?locations=UG.

[93] Ssenkaaba, Stephen. "Vector-Borne Diseases: The Plague Affecting Ugandans." *Www.newvision.co.ug*, 2014, www.newvision.co.ug/new_vision/news/1339434/vector-borne-diseases-plague-affecting-ugandans.

[94] "'When It Rains, My Heart Sinks': Climate Change Takes a Toll in Uganda." *UN Environment*, www.unenvironment.org/news-and-stories/story/when-it-rains-my-heart-sinks-climate-change-takes-toll-uganda.

natural swamp vegetation were replaced by agricultural crops, experienced higher temperatures. This microenvironmental change was thought to be a contributing factor to the increased risk for malaria in those cultivated areas.[95] Throughout constant land changes and increased temperatures, vector borne diseases that were once starting to diminish in Uganda are now resurging.

Malaria is the most common and deadly vector borne disease found in Africa. Sub Saharan Africa (the geographical area below the Saharan) was home to 90% of malaria cases and 92% of malaria deaths globally in 2015.[96] Uganda is one of the problematic countries in the Sub Saharan. There are high malaria endemics in 95% of the country, including 90% of the population of 33 million living in a high epidemic area[97] (see figure 4). Malaria is still the major cause of death in Uganda with approximately 70,000 to 100,000 Ugandans dying each year from the disease; with about half of the diseased being children. [98]

Uganda's economy and poverty is significantly impacted by malaria. Clinically diagnosed malaria accounts for 30-50% of outpatient visits at health facilities, 15-20% of all hospital admissions, and up to 20% of all hospital deaths.[99] Uganda citizens who are already experiencing extreme poverty have to pay for expensive health consultations, drugs and transportation to far away health facilities. Malaria also has a large impact on the economy through time off work and sick days. Malaria costs a family on average 9 US dollars, or 3% of their annual income as workers suffering from malaria may be unable to work for an estimated 5-20 days per episode.[100] Malaria also affects the future of the country as it impacts a child's

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[95] Vora, Neil. "Impact of Anthropogenic Environmental Alterations on Vector-Borne Diseases." *Medscape Journal of Medicine*, Medscape, 2008, www.ncbi.nlm.nih.gov/pmc/articles/PMC2605134/#R13.

[96] "10 Facts on Malaria." *World Health Organization*, World Health Organization, 13 Dec. 2016, www.who.int/features/factfiles/malaria/en/.

[97] Yeka, Adoke, et al. "Malaria in Uganda: Challenges to Control on the Long Road to Elimination: I. Epidemiology and Current Control Efforts." *Acta Tropica*, U.S. National Library of Medicine, Mar. 2012, www.ncbi.nlm.nih.gov/pmc/articles/PMC3156969/.

[98] Wetaya, Richard. "Malaria Leading Cause of Death in Uganda." *Www.newvision.co.ug*, May 2016, www.newvision.co.ug/new_vision/news/1423973/malaria-leading-cause-death-uganda.

[99] "National Malaria Control Program." *Ministry of Health*, health.go.ug/programs/national-malaria-control-program.

[100] National Malaria Control Program." *Ministry of Health*, health.go.ug/programs/national-malaria-control-program

school attendance and learning capability. Severe malaria impairs children's learning and cognitive ability by as much as 60%.[101] This will affect their performance in primary and secondary school.

Uganda has high aspirational goals for dealing with malaria in its future. These goals are set by the National Malaria control program and include:

- By 2020, reduce annual malaria deaths from the 2013 levels to near zero (near zero implies less than 1 death per 100,000 population)
- By 2020, reduce malaria morbidity to 30 cases per 1000 population (that is 80% reduction from the 2013 levels of 150 confirmed malaria cases per 1000 population)
- By 2020, reduce the malaria parasite prevalence to less than 7% (over 85% reduction in malaria parasite prevalence from a baseline of 45% in 2010)

One way to try and reach Uganda's goals is through medication. Malaria in Uganda was controlled more efficiently in the early 2000's. Prior to 2004, trained volunteers were in charge of administering "HOMEPAK" an at-home treatment including a prepackaged combination of the drugs chloroquine and SP. [102] However, in 2004, significant drug resistance was found to both of the two prepackaged drugs. "Home-based treatment of malaria using chloroquine and SP didn't have a big effect. One major factor was that the malaria parasites were already resistant to the drugs," declared Professor Umberto D'Alessandro from the Prince Leopold Institute of Tropical Medicine in Antwerp, Belgium.[103] Since the resistance was declared, artemisinin combination therapy (ACT) drugs such as Coartem have been used as well. However, it is

[101] National Malaria Control Program." *Ministry of Health*, health.go.ug/programs/national-malaria-control-program
[102] "Treating Malaria at Home in Uganda." *World Health Organization*, World Health Organization, 4 Mar. 2011, www.who.int/bulletin/volumes/84/10/06-021006/en/.

[103] "Treating Malaria at Home in Uganda." *World Health Organization*, World Health Organization, 4 Mar. 2011, www.who.int/bulletin/volumes/84/10/06-021006/en/.

acknowledged that the mosquitos could also develop resistance to these drugs. Therefore, the distribution and injection instructions are very specific and highly regulated.

Uganda is also trying other solutions to control the severe malaria issue of vector control on a wide sale. Residential sprays and bed nets are becoming more desirable and an effective way to keep vetors away from human households. In Uganda, it is also important to control vector control throughout urbanization. Action plans in 2003 were created and suggested in Kampala, namely the filling of puddles, introducing larvivorous fish and improving drainage and in Jinja, the plans focused on building and repairing drainage channels and soak-pits. [104]

[104] National Malaria Control Program." *Ministry of Health*, health.go.ug/programs/national-malaria-control-program

Canadian Connection

Canada is the second largest country in land area in the world with a smaller population of 37 million. Canada is a developed country and it has a well structured healthcare system and a poverty rate of under 10 percent. Canada has a varying climate. In the most populated areas near the American border the weather consists of four distinct seasons. The summer months can range up to 35 degrees celsius while it is not uncommon for winters to have regular temperatures of -25 degrees celsius. [105] Canada is the 12th largest exporter in the world with it's top exporters being crude petroleum, cars, refined petroleum and vehicle gas.[106] Canada had a GDP of $1.65T as of 2017. Canada has a variety of different landscapes including: plains, mountains, forests, valleys and multiple lakes and rivers.

Canada does not have many prevalent vector borne diseases due to the harsh winters. However, a disease that has been an increasing issue since 2002 from the Culex genus of mosquitoes is west nile virus (see figure 5). West nile virus is usually spread by a mosquito biting a infected bird and then biting a human. Most cases show symptoms two to fifteen days after infection. These symptoms are typically very mild and fewer than one percent of affected people will develop serious symptoms.[107] However, serious symptoms can directly affect the central nervous system including the brain and spinal cord and could potentially be fatal. Blood banks in Canada have started screening for yellow fever to avoid transmission. In 2017 there

[105] "The Climate In Canada ." *About Studying in Canada - Study Canada*, 2003, www.studycanada.ca/english/climate.htm.

[106] "Canada." *OEC - Canada (CAN) Exports, Imports, and Trade Partners*, atlas.media.mit.edu/en/profile/country/can/.

[107] Public Health Agency of Canada. "Symptoms of West Nile Virus." *Canada.ca*, 26 June 2015, www.canada.ca/en/public-health/services/diseases/west-nile-virus/symptoms-west-nile-virus.html.

were 200 clinical cases found across Canada.[108] The 200 cases mostly consisted of the severe symptoms as most cases of west nile virus presents like the flu, making it difficult to test how frequent the disease actually is. West nile virus has became a problem in first nations reserves where housing conditions and health care is not always ideal.

Lyme disease is the other vector borne disease becoming increasingly prevalent in Canada. Different to many other vector borne diseases, lyme disease is spread by a black legged tick instead of a mosquito. For ticks to survive, they need to attach to a source. In Canada, the ticks will attach onto either birds or rodents and become infected with the lyme disease bacteria (Borrelia burgdorferi). This bacteria is transferred to humans when the tick chooses the human as a host. Anywhere from 3 to 30 days after being bitten, a human can develop flu like symptoms. If these symptoms are not treated, the case of lyme disease can progress to being serious. In serious cases, lyme disease can lead to facial paralysis, heart disorders, neurological disorders, severe arthritis and even death. [109]

Canada is a developed country with a strong health care system. In the past, Canada had no issues with vector borne disease. The reason why they are starting to grow in Canada is due to climate change. The geographical expansion of vectors is due to warmer temperatures resulting from climate change. Climate change also brings the potential for new vectors to become established. The Asian tiger mosquito also called Aedes albopictus , a vector for dengue, zika, yellow fever and chikungunya viruses, is currently found as far north as the northeastern US, with the northern edge of its range being limited by winter temperature.[110] Aedes aegypti mosquitoes are already seen in Canada (see figure 6). Aedes mosquitoes are urban bugs that like small pools of water that do not fully freeze. As winters are becoming less harsh, these small pools of water will not fully freeze and attract more aedes mosquitos.

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[108] Public Health Agency of Canada. "Surveillance of West Nile Virus." *Canada.ca*, 24 Dec. 2018, www.canada.ca/en/public-health/services/diseases/west-nile-virus/surveillance-west-nile-virus.html.

[109] Public Health Agency of Canada. "Symptoms of Lyme Disease." *Canada.ca*, 13 June 2017, www.canada.ca/en/public-health/services/diseases/lyme-disease/symptoms-lyme-disease.html.

[110] Hierlihy, Catherine. "Climate Change and Vector-Borne Illness." *Canadian Public Health Association | Association Canadienne De Santé Publique*, 2017, www.cpha.ca/climate-change-and-vector-borne-illness.

Canada needs to put preventative measures in place before the vector situation worsens. Canadian citizens need to be conscious of having potential breeding spots for vectors around their property. Clearing any source of standing water can be helpful for reducing mosquito habitats including, tires, children toys and flower pots. For ticks, it is essential to keep grass cut short and be cautious around pets for transmission. When venturing into the woods or other potential vector breeding sites it is important to wear light coloured clothing, covering most of the body and to wear bug repellent containing chemicals DEET or Icaridin.[111] For west nile virus, humans when hunting need to be conscientious of handling dead animals, specifically birds, First Nations residents, Chiefs and councils, leaders and community workers are additionally having access to information sessions on west nile virus. There is not a cure so far for west nile virus; progress is primarily through symptom management. Alternatively, lyme disease has a cure. Normally it can be treated with 2- 4 weeks of antibiotics unless the symptoms are severe.[112] If a tick is removed between 24 and 36 hours after infection an infection is unlikely to develop.[113] Humans are encouraged to remove ticks themselves with tweezers by following instructions on the government of Canada's website. If it is outside of the person's comfort level, it is imperative to see a physician to remove the tick as soon as possible. If possible, when ticks are removed and preserved, it is recommended to send them to the provinces public health laboratory for testing of lyme disease.

In conclusion, vector borne diseases are a minor problem in Canada. However, the ever changing climate in Canada will create a more favourable habitat for them to prosper in. The milder winters will allow vectors to stay alive year round. Basic preventative measures have been put in place, however more needs to be done in order to establish vector control throughout Canada.

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[111] Public Health Agency of Canada. "Prevention of West Nile Virus." *Canada.ca*, 8 Apr. 2016, www.canada.ca/en/public-health/services/diseases/west-nile-virus/prevention-west-nile-virus.html.

[112] Public Health Agency of Canada. "Treatment of Lyme Disease." *Canada.ca*, 19 Oct. 2017, www.canada.ca/en/public-health/services/diseases/lyme-disease/treatment-lyme-disease.html.

[113] Public Health Agency of Canada. "Removing and Submitting Ticks for Testing." Canada.ca, 13 June 2017, www.canada.ca/en/public-health/services/diseases/lyme-disease/removing-submitting-ticks-testing.html.

Logic of Evil

Evil is a difficult term to define. According to the Collins dictionary, evil is used to refer to all the wicked and bad things that happen in the world.[114] At a playground, a twelve year old is picking on a scrawny seven year old. Most people can agree on the fact that the twelve year old is partaking in "evil" activities. However, if there is another twelve year old, a bystander, watching without coming to the aid of the victim, is this bystander also considered evil? This question pertains to the situation of vector borne diseases. The vectors would be considered the bully, the developing and poor countries would be the victim and the rich western world countries, with the resources to help, would be the uncommitted bystander. Like the bystander, the developed countries know what is going on but they do not bother to interfere.

On the World Health organization website, there is a page titled 'Neglected Tropical Diseases'. Many of the diseases listed are vector borne including Dengue, Chikungunya and Lymphatic filariasis.[115] These diseases are responsible for the deaths of hundreds of thousands of people. Why are they neglected? In doctor Fulford's opinion,

> infectious diseases and things like vaccines aren't high income generating for researchers and drug companies because they are not chronic diseases; once you cure it you are cured. So the amount of investment needed to invest in a new antibiotic or create a new vaccine is sometimes not financially rewarding for a private sector for profit company and so a lot of the research into effective vaccines is only funded by and not for profits.

Consequently, the lack of money companies get from research into vector borne diseases turns them away from the subject. In this case, money is clouding judgement and importance.

The governments are also avoiding the issue of vector borne diseases. When asking Dr. Fulford what governments were doing to help, she simply replied with "very little". However, Dr. Fulford did add "To be fair, I think governments are overwhelmed." The truth is, in Canada

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[114] "Evil Definition and Meaning | Collins English Dictionary." *Evil Definition and Meaning | Collins English Dictionary*, www.collinsdictionary.com/dictionary/english/evil.

[115] "Neglected Tropical Diseases." *World Health Organization*, World Health Organization, 28 May 2018, www.who.int/neglected_diseases/diseases/en/.

there are currently very few deaths due to vector borne diseases and thus little to no money from the government will be going into research trials. The governments of countries with high death rates from vector borne diseases are developing countries where the government does not have a lot of funding. Therefore there is little government support going to help.

Solutions

Environmental Management

Environmental management is altering the environment to make vector and human contact as minimal as possible. Some viable solutions include:

- Environmental modification – physical transformations to reduce vector habitats: installation of a reliable piped water supply to communities
- Environmental manipulation – frequent emptying and cleaning: cleaning of gutters, sheltering stored tires from rainfall, recycling or proper disposal of discarded containers and tires
- Changes to human habitation or behaviour – actions to reduce human–vector contact, such as installing mosquito screening on windows, doors and other entry points

Chemical Control

Indoor residual spraying consists of spraying the house with pesticides to reduce sand flies and bugs inside homes. Indoor spraying is effective for 3–6 months, and with the use of DDT can be effective for 6–12 months.[116] A more extreme measure is outdoor spraying or Aerial spraying . Some surfaces to be sprayed include domestic animal shelters, outdoor latrines, livestock before slaughter and other damp places can help control sandflies.[117] If aerial spraying is used early in an epidemic, the intensity of virus transmission can be reduced.

[116]"A Global Brief on Vector-Borne Diseases." *World Health Organization*, 2014, apps.who.int/iris/bitstream/handle/10665/111008/WHO_DCO_WHD_2014.1_eng.pdf?sequence=1.

[117] "A Global Brief on Vector-Borne Diseases." *World Health Organization*, 2014, apps.who.int/iris/bitstream/handle/10665/111008/WHO_DCO_WHD_2014.1_eng.pdf?sequence=1.

Biological/ Genetic Control

Biological control is a method of controlling mosquitoes and other vectors through the introduction of parasites, predators or other living organisms.[118] An example of this is the Larvivorous fish and copepods. They are effective in controlling the larvae of Aedes mosquito.[119] Native species to the country that eat the aedes mosquitoes are released to prey on the bugs. A less natural process than releasing native species is releasing genetically-engineering mosquitoes. These mosquitoes have Wolbachia bacteria so that they cannot reproduce. A current controlling attempt is using CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) by planting a deadly gene in mosquito DNA, and engineering it such that the modification would spread through each generation faster than nature intended.[120] The project succeeded and wiped out caged cohorts of the malaria-touting mosquito Anopheles gambiae in as few as seven generations.[121]

Medical Control

There are only two major vector borne diseases that have vaccinations. One vaccine is the Japanese encephalitis, approved for people two months of age and older. It is recommended for travelers to Asia who plan to spend at least a month in areas where JE occurs or have any other circumstances of possible exposure.[122] The best vaccination for a vector borne disease is the

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[118] "A Global Brief on Vector-Borne Diseases." *World Health Organization*, 2014, apps.who.int/iris/bitstream/handle/10665/111008/WHO_DCO_WHD_2014.1_eng.pdf?sequence=1.

[119] "A Global Brief on Vector-Borne Diseases." *World Health Organization*, 2014, apps.who.int/iris/bitstream/handle/10665/111008/WHO_DCO_WHD_2014.1_eng.pdf?sequence=1.

[120] Molteni, Megan. "Here's the Plan to End Malaria With Crispr-Edited Mosquitoes." *Wired*, Conde Nast, 25 Sept. 2018, www.wired.com/story/heres-the-plan-to-end-malaria-with-crispr-edited-mosquitoes/.

[121] Molteni, Megan. "Here's the Plan to End Malaria With Crispr-Edited Mosquitoes." *Wired*, Conde Nast, 25 Sept. 2018, www.wired.com/story/heres-the-plan-to-end-malaria-with-crispr-edited-mosquitoes/.

[122] "Japanese Encephalitis Vaccine | Japanese Encephalitis | CDC." *Centers for Disease Control and Prevention*, Centers for Disease Control and Prevention, 2019, www.cdc.gov/japaneseencephalitis/vaccine/index.html.

yellow fever vaccine. A safe and effective option has been available for more than 80 years. The vaccine is a live, weakened form of the virus given as a single shot. A single dose provides lifelong protection for most people.[123]

Some treatments are available for certain vector borne diseases. For lymphatic filariasis, single doses of albendazole plus either diethylcarbamazine or ivermectin are given to the entire population at risk every year for at least 5 years will prevent transmission.[124] For malaria, treatments with a variety of different types of drugs are used to prevent resistance. Some of the drugs include: chloroquine, Atovaquone-proguanil (Malarone®), Artemether-lumefantrine (Coartem®), Mefloquine, Quinine, Doxycycline (used in combination with quinine), Clindamycin (used in combination with quinine), Tetracycline (used in combination with quinine) and Artesunate (not licensed for use in the United States, but available through CDC).

Personal Protection

Insecticide nets are one of the simplest and most cost effective measures in preventing vector borne diseases. The budgets are primarily made to prevent malaria but they are also effective against sandflies and triatomine bugs. It is suggested for people who are at risk for malaria to sleep under bug nets for the two or three years (how long the nets typically last). Between 2004 and 2013, international donors funded over 700 million bug nets to protect families against malaria in sub-Saharan Africa.[125]

Insect repellents are also a very common solution. DEET (N,N Diethyl-meta-toluamide) or two other recently approved compounds IR3535 and KBR 3023 are the contents that drive away vectors.[126] Repellants can last anywhere from fifteen minutes to ten hours. The suggested

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[123] "Yellow Fever Vaccine." *Centers for Disease Control and Prevention*, Centers for Disease Control and Prevention, 2019, www.cdc.gov/yellowfever/vaccine/index.html.

[124] "A Global Brief on Vector-Borne Diseases." *World Health Organization*, 2014, apps.who.int/iris/bitstream/handle/10665/111008/WHO_DCO_WHD_2014.1_eng.pdf?sequence=1.

[125] "A Global Brief on Vector-Borne Diseases." *World Health Organization*, 2014, apps.who.int/iris/bitstream/handle/10665/111008/WHO_DCO_WHD_2014.1_eng.pdf?sequence=1.

[126] "A Global Brief on Vector-Borne Diseases." *World Health Organization*, 2014, apps.who.int/iris/bitstream/handle/10665/111008/WHO_DCO_WHD_2014.1_eng.pdf?sequence=1.

clothing to wear in high density vector areas include light coloured pants and long sleeves. Pre-Treated outdoor clothing is also available with chemicals embedded in the materials.

Religious Opposition to Solutions

Some citizens object to getting vaccines due to religious reasons. There are normally two common objections: the ethical dilemmas associated with using human tissue cells to create vaccines, and beliefs that the body is sacred, should not receive certain chemicals or blood or tissues from animals, and should be healed by God or natural means.[127] It is important to respect these religious believes even though it can lead to small outbreaks. Religious and political objections by Muslim fundamentalists have driven suspicions about the polio vaccine in Pakistan, Afghanistan, and Nigeria. For example, the local Taliban in Southern Afghanistan have called polio vaccination an American ploy to sterilize Muslim populations and an attempt to avert Allah's will. Resistance to vaccination has even resulted in violent beatings and kidnappings.[128]

Many religions are also split on their opinions of genetic mutations such as the crispr system. Judaism offers many tales of people participating in genetic mutation. Stories and parables about people creating synthetic life are mentioned in Jewish texts — notably the Talmud and the Zohar. [129] Muslim and Hinduism both take a similar approaches in that there are no particular principles that could be seen as a basis for prohibiting biotech development.[130] However, Christianity is very divided on this issue. The outlook of 'playing god' is very bothersome to some Christians as humans are creating something that god did not.

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[127] "Cultural Perspectives on Vaccination." *History of Vaccines*, 2018, www.historyofvaccines.org/index.php/content/articles/cultural-perspectives-vaccination.

[128] "Cultural Perspectives on Vaccination." *History of Vaccines*, 2018, www.historyofvaccines.org/index.php/content/articles/cultural-perspectives-vaccination.

[129] "How Religious Beliefs Shape Our Thinking on Cloning, Stem Cells and Gene Editing." *Genetic Literacy Project*, 11 Jan. 2019, geneticliteracyproject.org/2018/11/09/cloning-stem-cells-gmos-religious-beliefs-shape-thinking/.

[130] "How Religious Beliefs Shape Our Thinking on Cloning, Stem Cells and Gene Editing." *Genetic Literacy Project*, 11 Jan. 2019, geneticliteracyproject.org/2018/11/09/cloning-stem-cells-gmos-religious-beliefs-shape-thinking/.

Conclusion

This report highlights that the world issue of vector borne diseases is not primarily about bugs. Yes, many mosquitos and ticks are spreading the disease but the problem expands to more than just killing vectors. Vector borne diseases in the developing world creates: high fatality rates of the young population, poor quality health care, undesirable travel locations and reduced people fit for work. Therefore, vector borne diseases ties directly into the deteriorating economy of developing countries. Vector borne diseases are also in direct relation to other prominent world issues such as climate change and poor urbanization. The issue of vector borne diseases underlines the selfishness of the western world. Due to the lack of financial gain, little funding is put to eradicating vector borne diseases. However, if the western world does not start to address this problem; the problem will address them. If dramatic changes are not made and solutions are not executed, vector borne diseases will soon be personally affecting the entire world's population.

Appendix

Figure 1.1

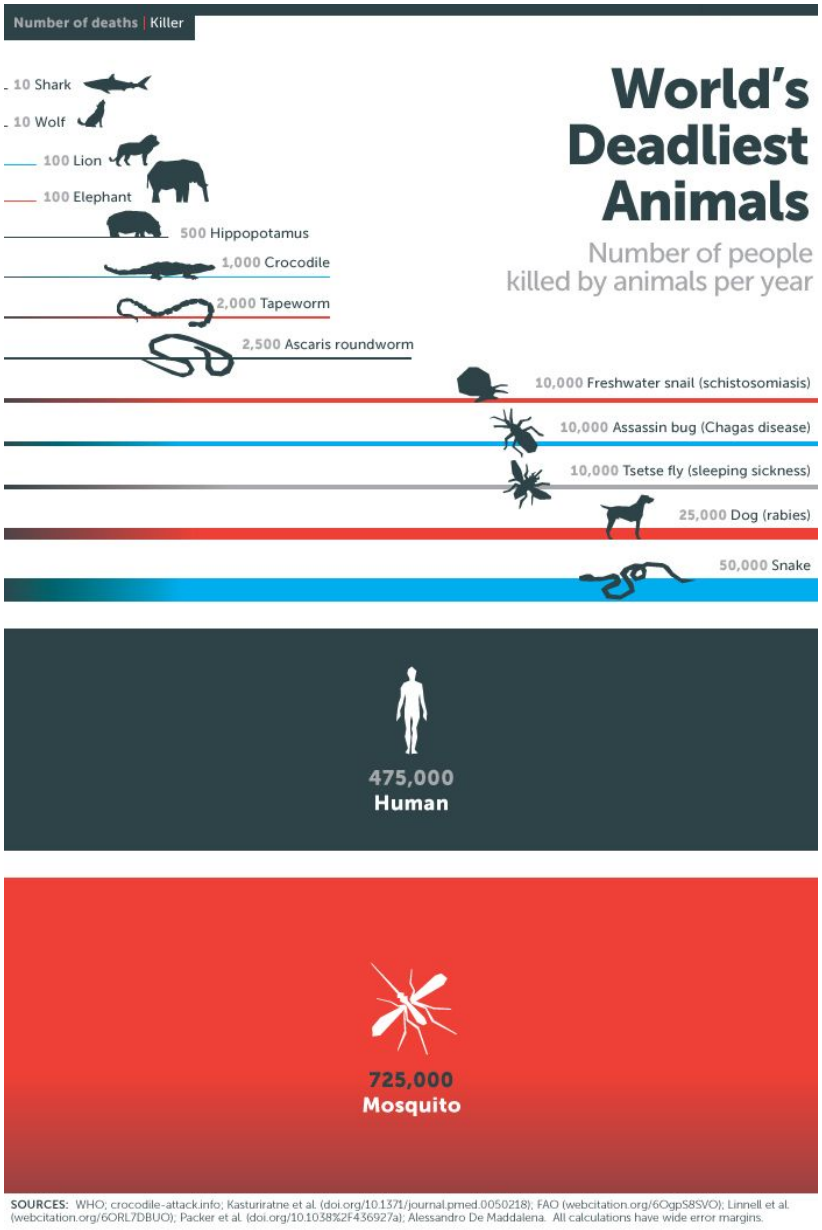


Figure 1.2

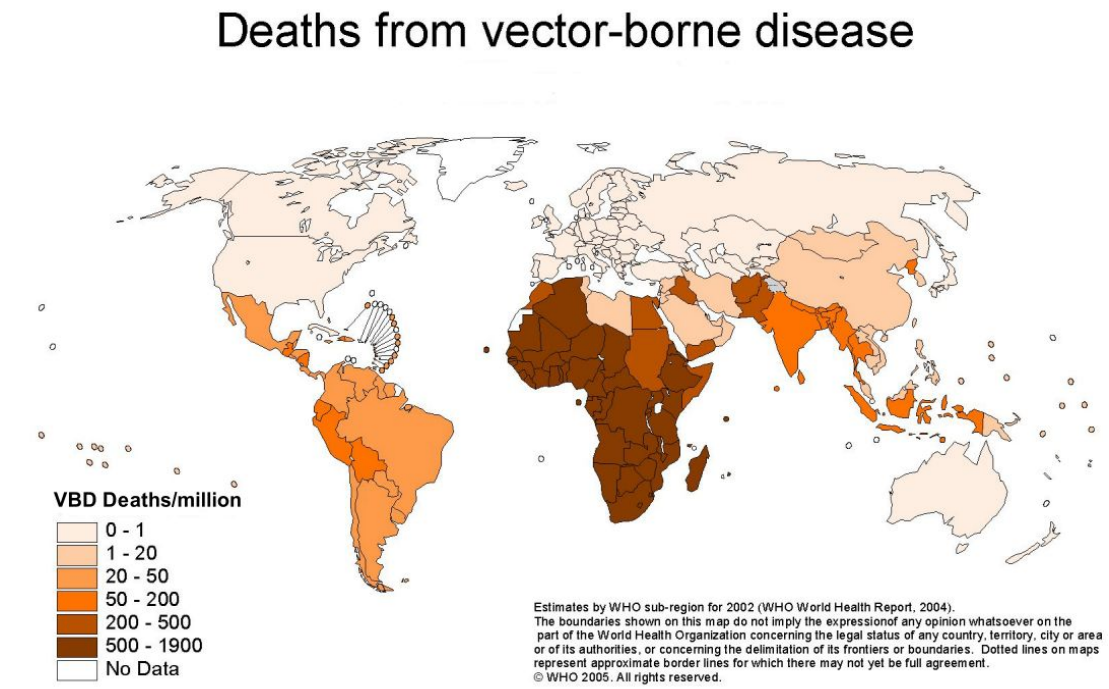


Figure 1.3

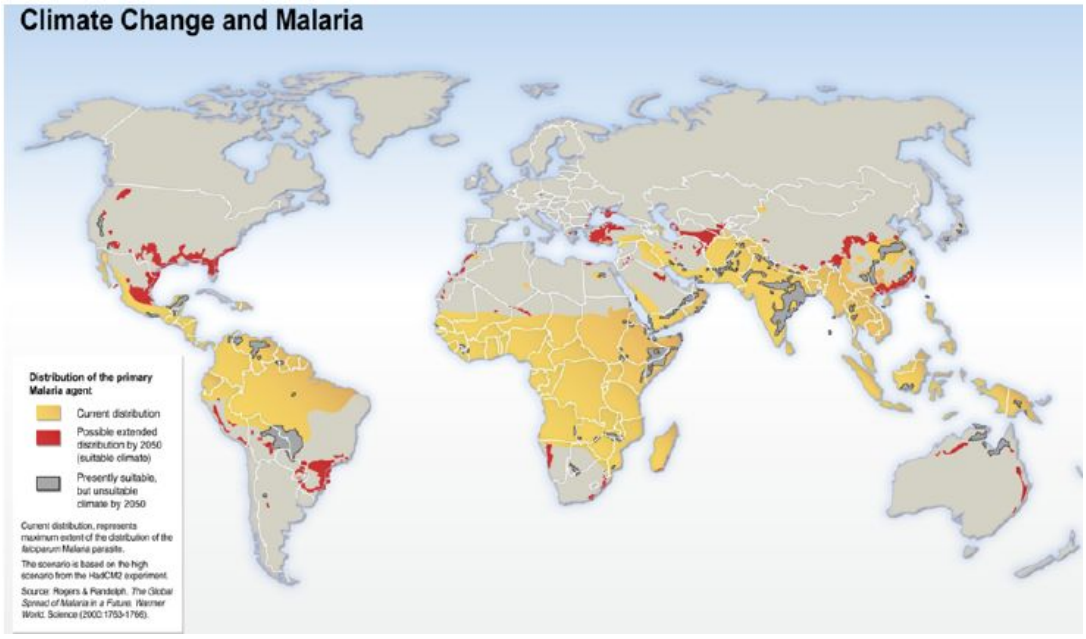
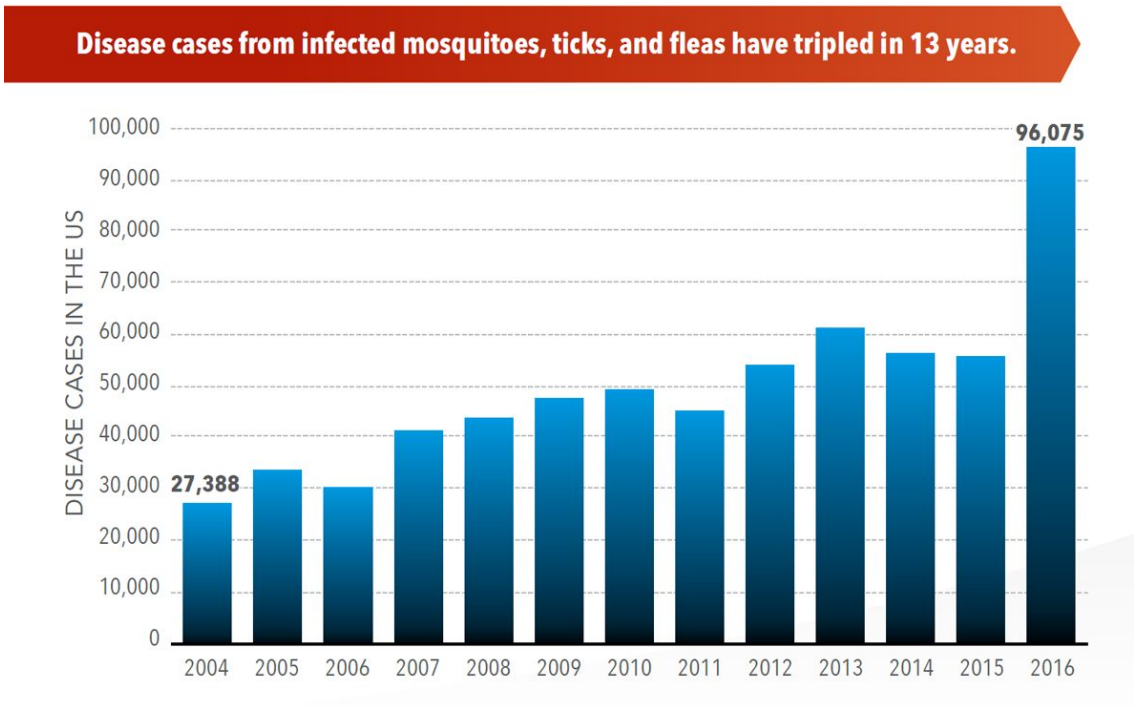


Figure 2.1



SOURCE: Rosenberg R, et al. Trends in Reported Vector-Borne Disease Cases—United States and U.S. Territories, 2004-2016. MMWR Morb Mortal Wkly Rep. Vol. 67, 2018.

Figure A - Interview with Dr. Martha Fulford

Q; What position do you currently hold

A; I'm an Infectious disease specialist. We go to medical school, go to residency and then we become an infectious disease doctor. We call ourselves ID docs. I've also done additional travel and studied tropical related illnesses and I've worked overseas a lot specifically in South Africa. So just by virtue of that people will come to me when they have just your type questions. So I end up being one of the people that deal with your type of questions.

Q: Could you give me a brief outline of what you know about vector-borne diseases and how they are spreading and rising?

The vector-borne disease is a huge term, when we use that term we are largely thinking of diseases that are spread by insects or arthropods. But a vector is anything that can transmit something. Probably the most prevalent and most severe concerning of the vector-borne diseases are the mosquito-borne diseases. Malaria has the most mortality. Malaria is spread by one specific mosquito, the Anopheles mosquito. Italy has recently had outbreaks of malaria. There have been outbreaks in Florida and these are small and contained. If you look at the history of malaria it used to be all throughout Northern America. When the canal system was being built in Southern Ontario if you read the history of it, the thing killing the people building the canal was malaria. So we had the vectors here a long time ago. We got rid of them because of Public Health. If we start to see changes in climate or deteriorating public health measures, malaria could be reintroduced. More concerning for a lot of us is the vector Aedes. Aedes is the vector that causes most of the concerning viruses including dengue fever, zika, yellow fever, and chikungunya. Yellow fever used to cause major outbreaks in the US. Again, they haven't had it there for a long time because public housing mosquito control, but if you look at a map of the distribution of the Aedes mosquito it's well entrenched in the U.S. Aedes aegypti might just be a slightly better vector and that goes halfway up the U.S. Aedes albopictus, which is the other one goes even further north. And the range of the mosquito is increasing. If you would have asked me 5-10 years ago, I would have told you we do not have Aedes mosquitoes in Canada. This is no

longer true. Every summer now, Aedes mosquitoes have been found in the Windsor area. The reality is these mosquitoes are moving north. This is a result of climate change, warmer winters and it's also probably a changing environment because in large urban areas there are certain pools of water that never freeze now. Urbanization, really large urban centers, have small microclimates. The other feature of the Aedes mosquito is it is an urban mosquito. It breeds in very small pools of water. So once again there is an increase in large urban cities especially if they have poor waste management. In large landfills where you will find rubbish, after a rain you could have a habitat for a mosquito. So the introduction for the Aedes mosquito, for the dramatic spread of the added mosquito, means also reintroduction. So yellow fever is potentially deadly so I worry about that one. And dengue fever has spread across the US and spread dramatically throughout the Americas. It's already in parts of the US and it will move to Canada. There is a vaccine in progress. Not fully approved yet, but I'm not sure how good it is. Then there is zika which is a good example of one that was introduced and jumps to one of your other questions about travel. Zika virus was a disease that was well known but rare. It was named and described in Uganda in the 1950s. There were sporadic outbreaks throughout Africa and southeast Asia but when it hit Brazil it hit a population that had never been exposed and had no antibodies. And of course Brazil already had a lot of Aedes mosquitoes and zika was introduced because of travel. Almost certainly by somebody from Micronesia who had the virus in their blood arrived in the Americas and got bitten and that's how it started. It arrived in the Americas and fortunately for us, for the most part, doesn't cause disease, with the exception of potential for congenital abnormalities with about a 5% chance for every woman getting pregnant with the disease. Zika caused a lot of fear, a lot of economic devastation but not too much morbidity and mortality. But if the same outbreak happened with yellow fever you might have significantly higher morbidity. However we do have a very effective yellow fever vaccine despite dramatic shortage of it for the last few years. So that is sort of one example of it. Another good example of vector-borne diseases is Lyme disease. The tick never used to be found in Canada. Obviously it's here now as the range has moved North. It would survive partly because it got introduced but also because of being able to survive through the winters. There

are a lot of other tick-borne infections they are not introduced yet but if we have the vector, we're starting to find all it takes is one inch of exposure to have a disease start to spread.

Q Do you know what short term and long terms the rise of vector-borne diseases will have?

Economic devastations have an enormous effects we don't quite know. The impact of tourism for example when zika happened was massive. People canceled trips, there was fear, there's paranoia on what to do and that had an extreme impact on Brazil. Another example that isn't vector born is when Sars hit Toronto. I mean in the grand total number of cases there were that many. But, the fear that went with that probably cost billions economically. Similarly with ebola, which is not vector-borne and we haven't had a case of in Canada; the fear of this coming into our country cost us millions of dollars in terms of what people were doing to try to prevent it. So the economic devastation is potentially very severe. It diverts healthcare dollars and it has an impact on economics so it's pretty huge actually. Right now the tragic things to see is the horrible contraction which is the impact of climate change and poverty. A cyclone just hit Mozambique in southern Africa (Cyclone India). It is almost a guarantee that because of the breakdown in infrastructure, because of the storm, we are going to see mass increases in vector-borne diseases, specifically malaria. It is the perfect setup for Mosquito breeding with all the stagnant water and the breakdown of infrastructure. Those storms used to be once-in-a-hundred-years storms are now frequent and the spin-off from them is incredible. It is going to be very difficult for us to control diseases with more storms. We're seeing them all the time now and the environmental impact is huge. But that's one of the things that allow vector-borne diseases to flourish. Some of the vectors have been introduced through International economics. West nile virus was likely introduced from imports. We had the type of mosquito in Canada but the virus almost certainly got introduced by an import.

Q: How long do you think it will take for all of these decisions to make their way to Canada and other developed countries? And to be a health crisis in those areas?

Canada may be lucky because we still have bad Winters and no matter what, in the winter time they'll be a dramatic down. We don't see many vectors borne disease transmission through the winter months. We have also noticed problems though parts of the United States, for example

Hawaii, with the dengue fever. And there was a zika transmission in Florida. So the control sometimes helps. I can't give a guess. They are already here. So the fact is most of the vectors already exist. In terms of Europe and the US, it's already there and Australia has a whack load of them because they are a warm country. New Zealand is a little safer because they are a smaller country with not as many vectors and more control. But in Canada it's already there around the edges. It could be anytime, like who would have predicted zika? And with massive increases in international travel that's one risk. And of course the increase of displacement of people not just economically, out of different wars and refugees. People like me are very careful of the threat of spreading that humans present. If I see someone with a fever and then an unusual rash and lesions, it is essential to take a very, very, very, careful history of anywhere they have been, any bites, any contact with animals and any unusual foods consumed. So part of what my job entails is detective work so I always have to be thinking about is what I'm dealing with and what could be introduced.

Q: What are different governments doing to take action?

Very little. (see more in the logic of evil)

Q: What do you think are some solutions to this problem or ways to prevent further transmission?

Primary prevention is a good one. I mean on the environmental side the control of waterways is important. It's contaminated stegment water and so some of the huge flooding that happens and leads to breeding of mosquitoes. Things like getting rid of the mangrove forest and other natural places that used to exist that would stop major flooding is detrimental. So some of those things of trying to maintain natural controls that we used to have to prevent the spread of vector-borne diseases is important. In Costa Rica when they had their massive dengue outbreak, it was because they've gotten rid of a lot of this kind of stuff and built a bunch of rice fields. It had massive flooding leading to stagnant water everywhere. It is behavioral things like that that can change to prevent further transmission. There are other things that can be done like the

mosquito bed net. You can also get clothing with the same stuff in it as the nets. But that's really short term and that also implies a certain amount of money. Vaccine development would be helpful. Sadly, only yellow fever has a very effective vaccine. There is a vaccine in development for dengue. It did get introduced but there's been problems. It seems to actually make some kids worse. There's a very good vaccine for Japanese encephalitis. There are some vaccines for a few of the tick-borne illnesses. There was a vaccine created for lyme disease but it got taken off the market very quickly because it was not effective and it was unclear of who would use it or benefit from it. Vaccines also have to be funded which is an issue. Yellow fever vaccine was funded because we had huge outbreaks in the US and other developed countries. There has to be an incentive to fund the vaccine. Vector control is also essential. Some of the control of the factors can be public health measures.

Figure B- Interview With Dr. Gerald Evans

Q: How does your job related to this- what is your background?

I'm a medical doctor that specializes in infectious diseases. Around 15 to 20% of all that infectious diseases in the world are caused by vector borne diseases. I have to know a lot about them because I treat people with diseases that are vector borne. Here in Canada, I am dealing mostly with lyme disease. I'm involved with a lot of research with the rise of that particular disease.

Q: What do you think are the long and short term effects of this rise?

You look at temperate climates like Canada it is apparent that vectors have expanded their range of where they were formally found. This is due to the fact that the climate is milder and they survive over winter when they never used to. Vectors can complete their life cycle in Canada. Mosquitoes that transmit zika and chikungunya are tropical mosquitoes but some parts of Canada are now so warm that they are able to survive there. Change is one of the major things related to the rise.

Q: What are the effects on the economy ?

Most temperate countries are thriving in their part of the developed world. Economical effect to the developed nations is not significant but it has the potential to be if a lot more people are getting infected. Some of these vector borne irises can also affect farm animals.

Q: How long for it to become a Canadian health emergency?

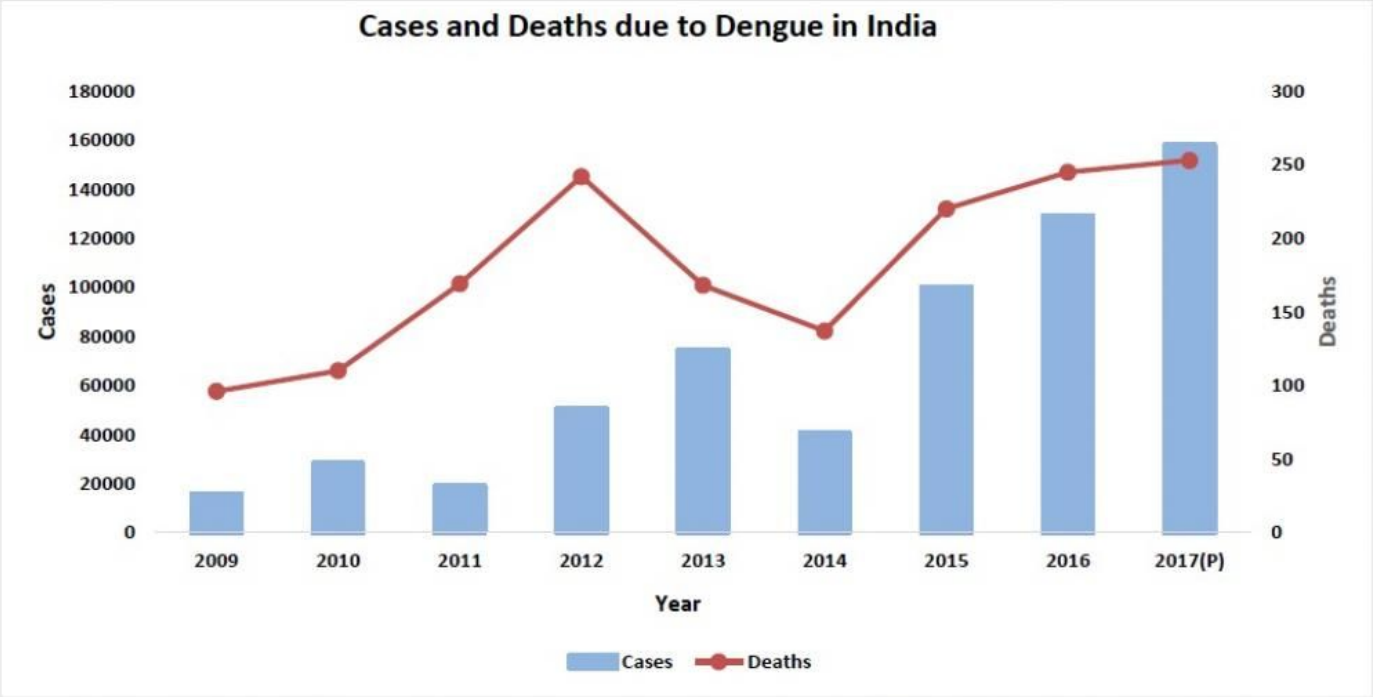
If you look at the emergence of lyme disease, it's in quite a few pocket in Canada now. I've seen projections of maps that show the expansion of the tick population and the population is going to be rich for things like lyme disease and other tick-borne infections. It is going to increase pretty significantly within the next 10 to 20 years. It really depends on if we could get a handle on

climate change and reduce the speed on which the planet is warming. That could really help. Right now, as you know, little is being done about climate change.

Q: Why is the government and other companies not doing much to help?

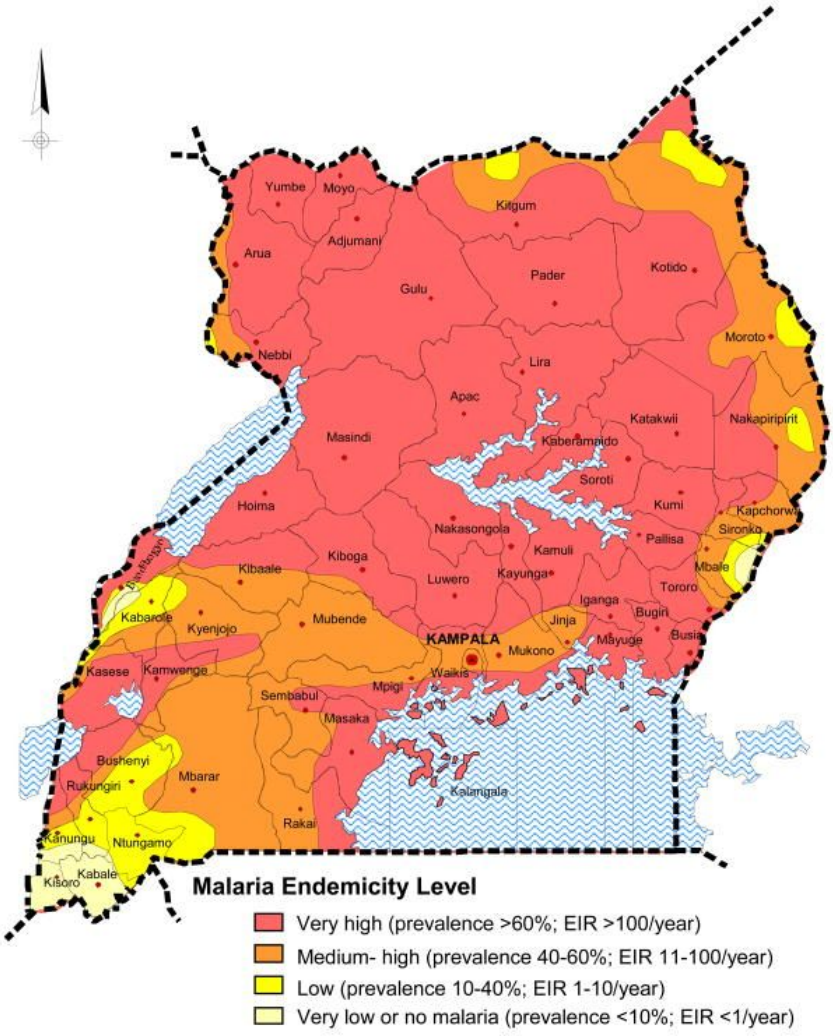
Even though there are some cases in Canada the percentage of people who are sick in Canada due to vectors is a very very small percentage. If Canada was a tropical country we would have to deal with really common tropical diseases like malaria and a bunch of other things. Right now the effect on Canada is low so the government's need to put money into it is very small. Lyme disease is emerging to become a very big problem but it may never get to the size of problems of cancer, heart disease and strokes. Countries will only look into things when it impacts their economics.

Figure 3



***Source**: Directorate of National Vector Borne Disease Control Programme, Dte.GHS, Ministry of Health & Family Welfare*

Figure 4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Paillisa
Kiboga
Mbale
Kibaale
Luwero
Kayunga
Tororo
Iganga
Kabarole
Kyenjojo
Mubende
Jinja
Bugiri
KAMPALA
Mayuge
Busia
Mukono
Kasese
Kamwenge
Wakiso
Mpigi
Sembabul
Masaka
Bushenyi
Mbarar
Rukungiri
Kalangala
Rakai
Kanungu
Ntungamo
Kisoro
Kabale
Malaria Endemicity Level
Very high (prevalence >60%; EIR >100/year)
Medium- high (prevalence 40-60%; EIR 11-100/year)
Low (prevalence 10-40%; EIR 1-10/year)
Very low or no malaria (prevalence <10%; EIR <1/year)

Figure 5

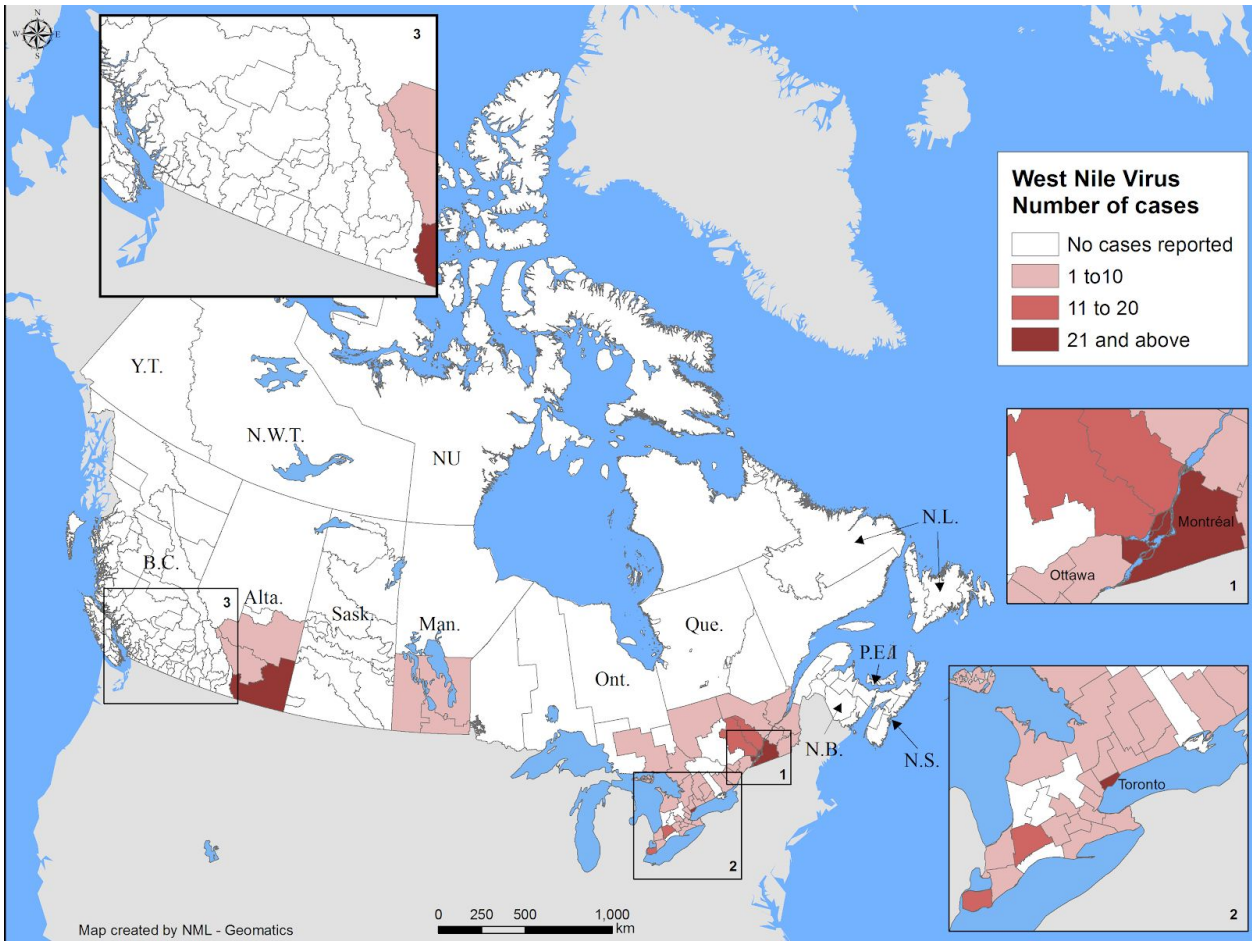

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Figure 6

2017 Enhanced mosquito surveillance

Surveillance Week	Number of Ae. aegypti mosquitoes trapped and identified	Results of Zika virus/West Nile Testing	Cumulative total # of Ae. aegypti mosquitoes found	Site (City or County)	Comments
August 14 to August 20 (Week 33)	1	Negative	1	City	Enhanced Mosquito Trapping
September 25 to October 1 (Week 39)	5	Negative	6	City	Field surveillance

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