Demystifying Climate Risk Volume I

Demystifying Climate Risk Volume I:

Environmental, Health and Societal Implications

Edited by

Carole LeBlanc

Cambridge Scholars Publishing

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In Memoriam

To Ed Helminski

Physicist, policy advisor, and publisher as well as a founder of the International Workshop on Solvent Substitution, central to the successful implementation of the Montreal Protocol in protecting the Earth's ozone layer. Always gracious; often funny.

To Dr. John Stemniski

Brilliant Draper Lab chemist, member of the Chemical Technical Options Committee (CTOC) of the Montreal Protocol, and individual recipient of the U.S. Environmental Protection Agency's Stratospheric Ozone Protection Award. My curmudgeon of a mentor and friend.

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PREFACE

On November 10, 2016, United States (U.S.) Senator Angus King, (Independent, Maine) presented, *Maine and Climate Change: The View from Greenland* as part of the Margaret Chase Smith Lectureship on Public Affairs. The Lectureship was endowed in 1989 by the Margaret Chase Smith Foundation in honor of Senator Smith's contributions to the state of Maine and to the nation. Senator King communicated much of the same information at a follow-up event at the University of Maine on November 16–explaining the causes and impacts of climate change over time; talking about what it was like to see Greenland's melting glaciers firsthand; and encouraging the student body to learn more about the science of climate change.

An advocate of climate science, the senator carries a 'climate change' card in his pocket, explaining that:

> "…the graphs on the card are the simplest and clearest way to show not only the unprecedented and growing amount of CO_2 <carbon dioxide> in our atmosphere, but also its close correlation to global temperatures in the past. As our climate continues to change and we strive to adapt…it is important that everyone appreciate the context of our situation with respect to data from the past."

While my family from Massachusetts often visited Maine, I'm a fairly new full-time resident of the state, having recently retired from many years of climate-related work. Maine is truly an exquisitely beautiful state, endowed with many environmental gifts throughout all of its seasonal changes. It comes as no surprise to me that native as well as 'newbies' to the state feel strongly about environmental issues and their consequences, both to human health and to nature.

On June 1, 2017 (just days before this book was finished), U.S. President Donald Trump, fulfilled a campaign promise by announcing his intention of withdrawing from the Paris Agreement. The agreement is the seminal global policy enacted to help ensure the world's retreat from ever-increasing temperatures.

On the same day, the U.S. Climate Alliance was announced. The alliance was spearheaded by the states of New York, California and

Washington, whose combined economies, according to the World Resources Institute, would be the fifth largest in the world. Entrance into the Alliance was swiftly followed by the states of Massachusetts and Vermont, both of which have Republican governors. At this writing, a total of 13 governors have joined the Alliance whose objectives include:

> "…achieving the U.S. goal of reducing carbon dioxide emissions 26-28 percent from 2005 levels by 2025 and meeting or exceeding the targets of the federal Clean Power Plan."

In addition, 17 U.S. governors have released individual statements in support of the Paris Agreement and 211 city mayors have adopted the Agreement's goals. To ensure that the U.S. remains a world leader in the reduction of carbon emissions, 125 cities, 9 states, 902 businesses and investors, and 183 colleges and universities have signed a similarly motivated declaration.[1] It is important to note that regionally enacted goals to reduce pollution may be easier to more accurately track and to monitor for progress.

Carole LeBlanc
Wells, Maine, USA

[1] The declaration represents 120 million Americans and $6.2 U.S. trillion economic power (www.wearestillin.com).

ACKNOWLEDGEMENTS

The editor would like to thank workshop co-chairs Barbara Kanegsberg, President BFK Solutions, LLC and Edward T. (Tom) Morehouse Jr., National Renewable Energy Laboratory (NREL) as well as the presenters and attendees to the *First Annual International Technical Workshop on Climate Risk*.

A special thanks in memory of Piers Sellers, then Acting Director of the Earth Sciences Division at NASA Goddard Space Flight Center. A climate scientist for many years, British-borne astronaut Sellers' discussion with Leonardo DiCaprio in the National Geographic documentary, *Before the Flood*, was particularly moving, following his diagnosis of cancer. Having broken my leg in a nasty fall that required surgery and a year-long recuperative period, I was considering cancelling the workshop. Though I never met Dr. Sellers, he graciously and kindly responded to my emails during this extraordinarily difficult time. His courage inspired me to continue this work.

Finally, the editor also thanks Cambridge Scholars Publishing for making this treatise possible.

INTRODUCTION

This book and its counterpart on industry and infrastructure are distillations of the *First Annual International Technical Workshop on Climate Risk* held in the autumn of 2016 in Wells, Maine in the United States (U.S.), an area of the country known for its environmental beauty. The workshop was serendipitously held only weeks before the U.S. presidential election.

The premise of the book is that long before the Paris Agreement[2], scientists, engineers, business men and women, public officials, academicians and non-governmental organizations (NGOs) throughout the U.S. and the world were hard at work in trying to solve the myriad of problems associated with anthropogenic (i.e., human-caused) climate change. The legislative force of the Montreal Protocol is now in support of the Agreement's key emission reduction goals by its inclusion of hydrofluorocarbons (HFCs), 'super' greenhouse gases used for refrigeration and air conditioning[3]. It was time for the seasoned leaders who implemented the Protocol, the world's most successful international treaty for the protection of the atmosphere[4], to share their knowledge and wisdom with the next generation of policy makers, technical professionals and educators before that expertise was lost.

Based on contributors' expertise and the multidisciplinary nature of climate change, topics ranged from an update on the outbreak of the Zika virus in this book to design modifications of drainage systems in response to increases in extreme weather events[5]. Material is organized into major themes, while maintaining each author's individual writing style.

This first volume on environmental, health and societal implications covers (in order of their appearance in the text):

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[2] The 2015 United Nations Climate Change Conference held November 30-December 12 that negotiated a consensus document on the reduction of climate change from the 196 countries in attendance.

[3] Originally introduced by the chemical industry to replace ozone-destroying chlorofluorocarbons (CFCs), HFCs are 3,830 times more potent than carbon dioxide (CO_2) with an atmospheric lifetime of 14 years.

[4] United Nations Development Program, *25 years of the Montreal Protocol: Partnerships for Change*, November 20, 2012.

[5] Available in the second volume, "Demystifying Climate Risk Volume II: Industry and infrastructure implications —workshop perspectives."

1. Environmental, health and societal impacts;
2. The special case of Africa; and
3. Advances in education and communication.

The second category became apparent only upon specific contributors' depictions of the disparate nature of human suffering caused by climate change across the globe. A separate volume covers industry and infrastructure implications.

The purpose of bringing these various communities of practice together was to:

- Leverage the many climate-related successes to date to inspire future innovations through 'lessons learned';
- Ensure that new atmospheric environmental regulations are timely communicated and economically executed; and
- Identify business opportunities for related sustainable development efforts.

As editor, I was struck by contributors' diverse fields and backgrounds, all working towards the common goal of climate protection. Consequently, several mini-interviews of authors are included and provide personal insight, so that the student reader might consider lending his/her own various talents to this endeavor as well.

It is my fervent hope that the contents of both volumes of *Demystifying Climate Risk* do just that: by translating the science of climate change, for advocates and naysayers alike, through real-life stories as told by practitioners themselves, the book's contributors, to whom I owe such gratitude and respect. Should we be successful, then U.S. Senator King's words will ring true:

> "Now is the time to address current and near-future climate related challenges. From clean and renewable energy sources, to efficiency technology and standards, to emission-reducing policies and incentives, there are many options at our disposal, many of which can foster economic growth and job creation. Like other complex challenges we have overcome in our past, no one single step will stop or reverse climate change alone; but, in combination, they represent a comprehensive framework that will help us pass on a stable and hospitable climate to future generations."

Chapter Summaries

Chapter One: *Zika Virus Introduction and Emergence in the United States (U.S.)*, by Dr. Ben Beard, clearly explains the origin, transmission, diagnosis and symptoms of this mosquito-borne disease. The first known cases of human infection by a mosquito bite in the continental U.S. occurred in Florida in July 2016. Fetal infection can result in brain abnormalities such as microcephaly and other congenital defects. The spread and, subsequently, the control and prevention of the disease are determined by a number of factors, including environmental conditions that influence vector (i.e., disease-carrying organism) populations. Human behavior, which is also influenced by climate and weather, is likewise a significant risk determinant.

Chapter Two: *Death by Degrees: The Health Crisis of Climate Change in Maine, U.S.*, by Karen D'Andrea, details the report of the same name by the Physicians for Social Responsibility Maine Chapter. The original 2000 report was updated in 2015. This paper outlines the report's findings for recent increases in asthma, allergies and vector-borne diseases for the state of Maine associated with global warming. In particular, the incidence of Lyme disease, which is carried by the deer tick, increased by 1300 percent (%) from 1998 to 2012 and can be considered the 'poster child' for climate change in Maine.

Chapter Three: *Putting Women in Power: An Analysis of Enabling Factors for Increasing Women's Participation in the Clean Energy Sector of the Global North*, by Maggie Roth, focuses on the disparate participation of women in the burgeoning fields of solar, wind, geothermal, hydropower, biofuels and ocean/tidal power in the developed countries of North America and Europe. This disparity may be due to factors such as a lack of requisite education, since data shows that while women compose 58% of college graduates, they represent only 4% of graduates in science, technology, engineering and math (STEM). The correlation between gender-sensitive energy policies in countries with a higher percentage of female STEM graduates is not straightforward, however. Besides clarifying the issues of education and policy, the paper recommends continued investment and research in clean energy as well as workplace flexibility, combating industry-based stereotypes, mentoring for leadership and training opportunities to further enable women's participation in the sector. Finally, Ms. Roth makes pointed recommendations for policymakers, women themselves, academia and corporations.

Chapter Four: *Sustainable Forestry Initiative Certification (SFI) and Carbon Markets–Opportunities and Barriers for SFI Program Participants in Maine*, by Alison Truesdale, thoroughly details the study of Maine's SFI-certified landowners' participation in carbon credit programs. The study is the result of collaboration between Maine's Implementation Committee of the SFI and Keeping Maine's Forests (KMF). California has the dominant cap-and-trade carbon credit market in North America, paying the highest prices for forestry projects that offset carbon emissions from the state's industries. Upon surveying the nine SFI participants in Maine, a heavily forested state, seven responded and reported to KMF that they had considered getting carbon credits through the California market, but had presently decided against it. Factors influencing their decision included costs, risks and the 100-year commitment required by carbon projects as not worthwhile at current credit prices. In particular, regulatory ambiguity of covered insured losses with regard to spruce budworm infestation, expected to occur in Maine two to three times within 100 years, may be too risky for current and prospective program participants. Carbon credits remain a viable option for landowners whose forestland portfolios have areas with high carbon stocking that can be maintained over the long term. Higher credit prices or poor wood markets could also tip the balance in favor of improved forestry management projects.

Chapter Five: *Climate Change and Sub-Saharan Africa: Agriculture and Food Security Nexus*, by Chizoba Chinweze, provides an overview of the status of food security for the 800 million inhabitants of Sub-Saharan Africa (SSA), 70% of whom rely on local agriculture for their sustenance. Climate change and, in particular, variability in rainfall amounts could have catastrophic results for SSA's 2,455 million hectares (mha), 173 mha of which are currently under cultivation, as approximately 97% of all crop land is rainfed and 43% of SSA's land mass is already composed of arid and semi-arid agro-ecological zones. Moreover, agriculture is SSA's most important economic sector, representing 70% of the labour force and 35% of the gross domestic product (GDP). Factors exacerbating climate change in SSA include endemic poverty, hunger, high prevalence of disease, chronic conflicts, low levels of development and low adaptive capacity. The confluence of these conditions can lead to dramatic swings in food prices as well as personal incomes. If related United Nations' Sustainable Development Goals (SDGs) are to be met, more concerted investments must be made and climate risk management strategies implemented.

Chapter Six: *Ecological and Infectious Disease Impacts of Hydropower in Sub-Saharan Africa*, by Bethany Taylor, juxtaposes SSA's energy needs with environmental and health considerations. In 2014, more than 620 million people, 80% of whom live in rural areas, lacked access to electricity in SSA. SSA is the only region in the world where the number of people living without electricity is increasing faster than efforts and progress to provide it. Renewable hydropower (that is, electric power that stores the potential energy of water in a reservoir and uses the kinetic energy of falling water) is currently contributing to more than 50% of electricity in 25 African countries but generally does not serve rural areas. While investment costs are high, once constructed, a hydropower plant has low operating costs, long plant life, no direct waste and low greenhouse gas (GHG) emissions. Dams and reservoirs in SSA to produce hydroelectric power, however, can have devastating and long-lasting effects on the health of local, upstream and downstream populations as well as ecological systems, including: sedimentation and erosion associated with impacted river flow, displacement and drowning of terrestrial flora and fauna, loss of habitat, changes in migration patterns. Most notably, plant construction may also lead to the creation of localized, humid micro-climates, which may be further exacerbated by global warming, leading to increased vector populations such as malaria-causing mosquitoes. Annually, 500 million cases of malaria are reported globally with 90% of infections occurring in SSA. Rural populations are also vulnerable to typhoid, cholera, dysentery, gastroenteritis and hepatitis if access to clean water supplies is interrupted during construction. Consequently, an Environmental, Social and Health Impact Assessment, or ESHIA, must make clear the risks and benefits of hydropower on a case-by-case basis, involve local populations in decision-making processes and include recommended malaria control measures.

Chapter Seven: *Indicators: Leveraging Science to Communicate Climate Change Impacts and Risks*, by Michael Kolian, provides an overview of how indicators can be used to communicate climate change impacts and risks. In 2016, the U.S. Environmental Protection Agency (EPA) released its latest version of the report, *Climate Change Indicators in the United States*, summarizing a key set of indicators related to the causes and effects of climate change. A total of 37 indicators are grouped into six categories: GHGs; weather and climate; oceans; snow and ice; health and society; and ecosystems. EPA's indicators are (1) derived from observed or measured data, (2) have a scientifically-based relationship to climate change, and (3) rely on peer-reviewed science and sources of data from federal government agencies. The paper describes the indicator framework which includes (1) collaborative partnerships, (2) methods for transparent documentation and evaluation of indicators, and (3) the goal of advancing the science through the ongoing development of additional indicators. Indicators can be used to support resource planning and decision-making, especially with regard to resilience and adaptation planning. Indicators can also characterize patterns of observed changes and help reveal the relevancy of those changes. A few observed changes are mentioned such as sea level rise and coastal flooding. Lastly, indicators are important to better understand the important but complex connections between climate change and human health and well-being.

Carole LeBlanc
Wells, Maine USA

SECTION I.

ENVIRONMENTAL, HEALTH AND SOCIETAL IMPACTS

CHAPTER ONE

ZIKA VIRUS INTRODUCTION AND EMERGENCE IN THE UNITED STATES (U.S.)

C. BEN BEARD, PH.D.[1]

Disclaimer: The findings and conclusions in this report are those of the author and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Abstract

Zika virus is a mosquito-transmitted virus in the family Flaviviridae, closely related to dengue and yellow fever viruses. The virus is transmitted primarily through the bite of an infected mosquito, chiefly by *Aedes aegypti* and occasionally by *Aedes albopictus*. Before 2007, very few cases of Zika had been documented. Zika virus infections were first reported in the Americas in March 2015. Since that time, cases have spread throughout the Americas with the first cases of locally-transmitted Zika illness reported in the U.S. in July 2016. The most serious concern

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[1] Centers for Disease Control and Prevention (CDC), Division of Vector-Borne Diseases, Fort Collins, Colorado (CO), U.S. Dr. Beard joined CDC's Division of Parasitic Diseases, where he served as Chief of the Vector Genetics Section from 1999 to 2003. In 2003, he moved to CDC's Division of Vector-borne Diseases in Fort Collins, CO to become Chief of the Bacterial Diseases Branch. In this capacity, he coordinated CDC's programs on Lyme borreliosis, tick-borne relapsing fever, Bartonella, plague, and tularemia. In addition to his work as Chief of the Bacterial Diseases Branch, in 2011 Dr. Beard was appointed as the Associate Director for Climate Change in CDC's National Center for Emerging and Zoonotic Infectious Diseases where he coordinated CDC's efforts to mitigate the potential impact of climate variability and disruption on infectious diseases in humans. Currently he serves as Deputy Director of CDC's Division of Vector-Borne Diseases. During his 25-year tenure at CDC, Ben has worked in the prevention of vector-borne diseases, both in the domestic global arenas. For additional biographical insights to the author's work, see the 'Following-up' section at the conclusion of this chapter.

with Zika is the risk of congenital Zika virus infection, which has been associated with birth defects in 10% of fetuses or infants from completed pregnancies with laboratory-confirmed recent Zika virus infection. Zika virus introduction and spread in the Americas has likely been influenced by a number of contributing factors including global travel, immunologically naïve human populations, poor living conditions, inadequate public health resources, and environmental conditions conducive for populations of competent mosquito vectors to thrive.

Introduction

Zika is caused by infection with the Zika virus, a single-stranded RNA virus in the family Flaviviridae[1] (Fig. 1.1).

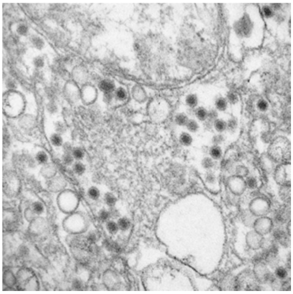

Fig. 1.1. Transmission electron microscope image of Zika virus [Photo credit: Cynthia Goldsmith]

It is closely related to dengue, yellow fever, Japanese encephalitis, and West Nile viruses and is transmitted primarily by mosquitoes, chiefly by *Aedes aegypti* and occasionally by *Aedes albopictus* (Fig. 1.2).

Fig. 1.2. Mosquito vectors of Zika virus. Left image, *Aedes aegypti*; right image, *Aedes albopictus* [Photo credits: James Gathany]

Additional modes of transmission also have been reported[2, 3] and are discussed below.

In 1947, scientists first identified the virus in a rhesus monkey in the Zika forest near Entebbe, Uganda[4] on the northern shore of Lake Victoria. The febrile rhesus monkey had been caged in the forest canopy as a sentinel for a yellow fever study (Fig. 1.3).

Fig. 1.3. Zika tower in the Zika Forrest, near Entebbe, Uganda [Photo credit: C. Ben Beard]

The virus was also recovered from the mosquito, *Aedes africanus*, caught in the same forest[4]. Prior to 2007, no outbreaks and only sporadic human cases of Zika were reported[5]. While it is likely that previous outbreaks were not recognized due to the symptoms Zika shares with many other diseases, the first reported outbreak of Zika occurred in 2007 in the state of Yap, Federated States of Micronesia.[5] The outbreak in Yap resulted in an estimated 5,000 infections in a population of less than 7,000 people. Based on a serosurvey, 73 percent of the population was infected and 18 percent of those infected developed clinical illness. Between 2013 and 2014, over 30,000 suspect cases were reported from French Polynesia and other Pacific islands[2,6]. The first cases of Zika in the Americas were reported in Brazil in March 2015 where infections were associated with Guillain-Barré syndrome[2,7]. In May 2015, the Pan American Health Organization issued an alert regarding the first confirmed Zika virus infection in Brazil. On January 22, 2016, the U.S. Centers for Disease

Control and Prevention activated its Emergency Operations Center to respond to the Zika outbreak in the Americas and increased reports of birth defects and Guillain-Barré syndrome in areas affected by Zika[8] (Fig. 1.4).

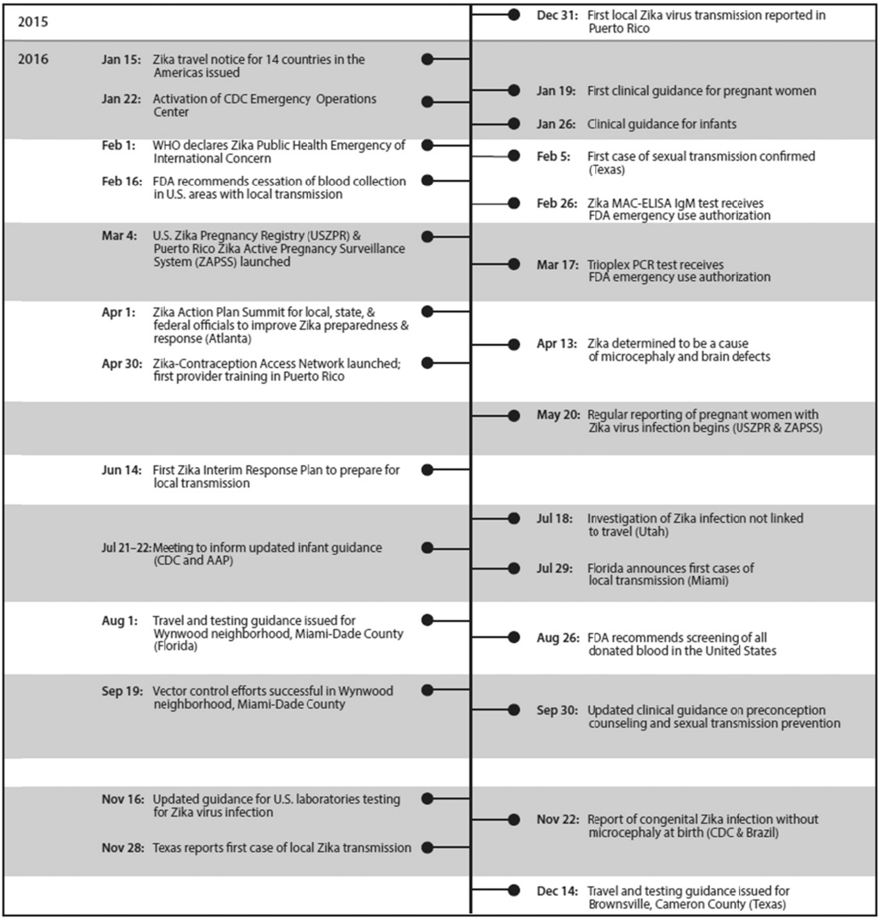

Fig. 1.4. Timeline for Zika virus response events–January–December 2016. Source: Oussayef NL, Pillai SK, Honein MA, et al. Zika Virus—10 Public Health Achievements in 2016 and Future Priorities. MMWR Morb Mortal Wkly Rep 2017;65:1482-1488. DOI: http://dx.doi.org/10.15585/mmwr.mm6552e1

By February 2016 when the World Health Organization declared the Zika virus outbreak a Public Health Emergency of International Concern somewhere between 440,000 and 1,300,000 cases were estimated to have occurred in Brazil.[9]

On July 19, 2016, the Florida Department of Health announced that it was investigating a possible non-travel associated case of Zika virus in Miami-Dade County, and on July 29th, it informed CDC that Zika virus infections in four people likely were caused by bites of local *Aedes aegypti* mosquitoes. These cases were the first known occurrence of local mosquito-borne Zika virus transmission in the continental United States[8,10].

Clinical illness

Following an incubation period of 3–14 days after being bitten by an infected mosquito[11], Zika virus infection can be asymptomatic or symptomatic. Zika virus disease is typically characterized by a tetrad of symptoms including acute onset of fever, maculopapular rash, arthralgia, and conjunctivitis, all of which may not be present in any given case of illness[5] (Fig. 1.5).

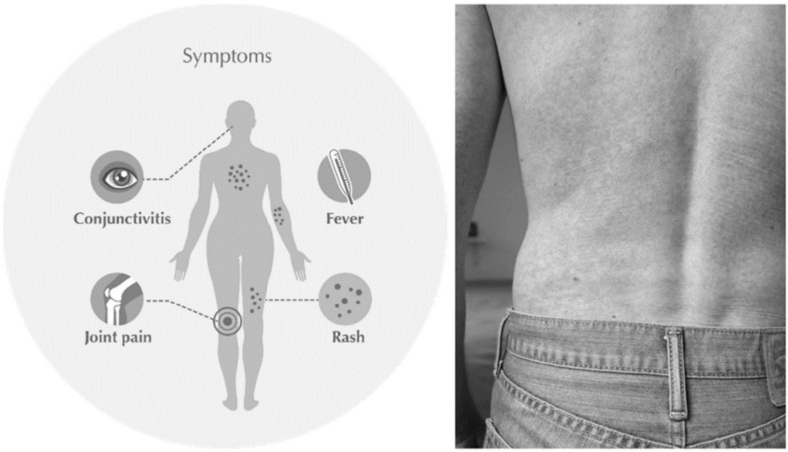

Fig. 1.5. Common symptoms associated with Zika virus infections. Left panel, tetrad of most common symptoms; right panel, blotchy rash that is characteristic of Zika. [Content provider: CDC]

Headache and muscle pain are also commonly reported. Symptoms, which typically last several days to one week, are generally mild. Severe disease requiring hospitalization is uncommon, and fatalities are rare. Fatal cases of Zika virus disease have been associated with severe thrombocytopenia[12,13]. While these cases are reminiscent of severe dengue, both the timing of symptom onset and the theorized mechanism of thrombocytopenia appear to be different from what has been reported for severe dengue[12].

The most serious concern associated with Zika virus infection is congenital Zika syndrome, a pattern of congenital anomalies linked to Zika virus infection during pregnancy[14]. If Zika virus infection occurs in a pregnant woman, the virus can pass from the woman to her fetus, resulting in infection of the developing infant. Fetal infection can cause microcephaly and other severe brain defects[14]. Congenital Zika infection has also been linked to abnormal eye development, hearing loss, limb deformities, and growth impairments[15]. In 2016, according to data reported to CDC from 44 U.S. states via the U.S. Zika Pregnancy Registry, 1,297 pregnancies with possible recent Zika virus infection were reported in the U.S. Zika virus-associated birth defects occurred in 10% of fetuses or infants from completed pregnancies with laboratory-confirmed recent Zika virus infection. Additionally, birth defects were reported in 15% of fetuses or infants of completed pregnancies with confirmed Zika virus infection in the first trimester[16]. These findings emphasize the serious risk for birth defects caused by Zika virus infection during pregnancy.

Diagnosis

Diagnosis of Zika virus infection relies on detecting either viral RNA that indicates current Zika infection or specific antibodies that may indicate recent infection, depending on prior exposure to Zika or related flaviviruses such as dengue. Viral RNA detection utilizes a nucleic acid test (NAT) that is currently recommended for use within 2 weeks of symptom onset due to the limited window of time in which the virus is circulating in peripheral blood. An anti-Zika IgM serologic test is recommended for detecting anti-Zika antibodies that can be indicative of recent Zika virus infection. If a symptomatic person lives in or recently traveled to an area with active Zika virus transmission, he or she should be tested. NAT testing should be performed for any pregnant woman who develops Zika symptoms or has sexual partners who test positive for Zika. A positive NAT test is confirmatory for Zika infection. A negative NAT test in a symptomatic pregnant woman should be followed up with both

Zika virus IgM and dengue virus IgM antibody testing. A positive IgM test result in this instance should be viewed with caution due to the possibility that exposure to Zika or dengue may have occurred prior to pregnancy. Asymptomatic pregnant women who have traveled to areas with posted CDC Zika Travel Notices or who have had sex with someone who has traveled to such areas should be tested using both NAT and IgM testing. Pregnant women who remain asymptomatic while living in an area of active Zika virus transmission should be tested at least three times during pregnancy using NAT testing. A woman living in an area of Zika virus transmission may also consider IgM testing for the presence of pre-existing IgM antibody as a part of pre-conception counseling. Recommendations for Zika testing are subject to change as new information becomes available. The most up-to-date information regarding which tests should be performed, the diagnostic specimen of choice, the timing of testing in regard to symptom onset, categories of risk, and other relevant questions can be found at the following website: https://www.cdc.gov/zika/hc-providers/types-of-tests.html.

Transmission

Zika virus is transmitted primarily by *Aedes* mosquitoes in the subgenus *Stegomyia*, among which *Ae. aegypti* is by far the most important vector species for transmission in humans[1,17]. Sylvatic transmission, as originally described in Africa, was linked to the zoonotic *Stegomyia* vector *Ae. africanus* in a transmission cycle involving non-human primates[4]. Putative or confirmed vector species in human outbreaks to date include *Ae. albopictus*, *Ae. hensilii*, and possibly *Ae. polynesiensis*[1, 18]. While a sylvatic cycle involving non-human primates has been identified in Africa, it is not yet known whether or not such a cycle will develop in the New World with non-human primates or other mammalian species. In the continental U.S., while both *Ae. aegypti* and *Ae. albopictus* are present (Fig. 1.6) to date all locally-transmitted cases have been linked to *Ae. aegypti*.

Vertical transmission has been observed at low rates in *Ae. aegypti* and *Ae. albopictus* for multiple flaviviruses and has been suggested for Zika virus based on a recent laboratory study[19]. This study showed that using experimentally-inoculated *Ae. aegypti*, vertical transmission to progeny could be achieved in a small proportion of individuals, reporting a filial infection rate of 1:290. No transmission took place in Zika virus inoculated *Ae. albopictus* mosquitoes. The investigators suggested that this phenomenon could possibly allow for survival of infected mosquitoes at low levels during adverse conditions in inter-epidemic periods. To date, vertical transmission of Zika virus has not been observed in field-collected mosquitoes. Therefore, the epidemiologic importance of these laboratory observations is yet to be determined.

Fig. 1.6. Estimated range of *Aedes aegypti* (left) and *Aedes albopictus* (right) in the United States, 2016. Source: https://www.cdc.gov/zika/vector/range.html

In addition to mosquito-borne transmission, Zika virus transmission has been reported to occur by a number of other routes including intrauterine and perinatal transmission, sexual transmission, laboratory exposure and blood transfusion[1, 3]. The most important of these by far is transmission that can occur from a pregnant woman to the fetus leading potentially to microcephaly, a condition which occurs at a rate of somewhere between 1 and 13%, with a greater risk associated with first trimester infections[16,20]

Current situation

Zika virus continues to spread globally to new areas where competent mosquito vectors are present. Currently, the World Health Organization (WHO) reports 84 countries, territories, or sub-national areas where local, vector-borne transmission has occurred, including 61 areas with new introduction or re-introduction since 2015 with ongoing transmission[21]. WHO further reports 18 areas where transmission was reported to have occurred prior to 2015 or where transmission is occurring but not related to recent introduction and five areas where transmission has been interrupted but remains at risk due to the presence of competent mosquito vectors. Cases continue to be reported, but the expansion to new countries and regions appears to be leveling off[22] (Fig. 1.7).