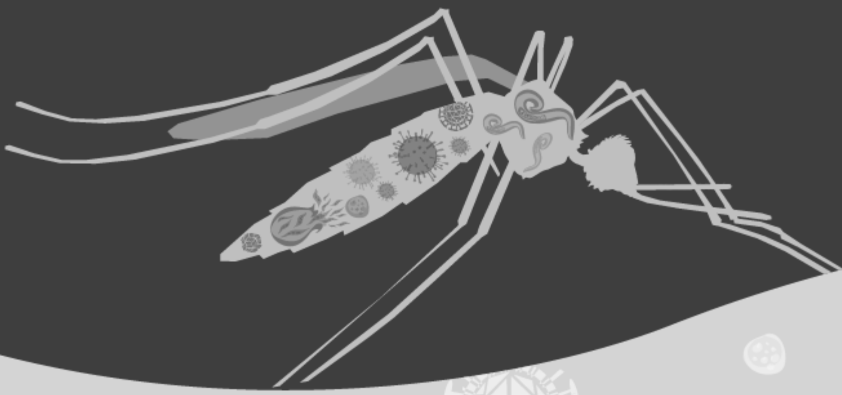


BEYOND THE BITE

GLOBE Mission Mosquito Disease Guide

INSTITUTE for GLOBAL ENVIRONMENTAL STRATEGIES

ABOUT THIS PROJECT

GLOBE Mission Mosquito is co-led by the Institute for Global Environmental Strategies and NASA Goddard Space Flight Center, working in collaboration with the GLOBE Implementation Office.

This campaign engages teachers and students, informal science education providers, citizen scientists, and scientists to use the Mosquito Habitat Mapper tool in NASA's GLOBE Observer app to collect data on mosquito larvae - an immature form of mosquitoes that do not bite or spread disease – and eliminate standing water in containers, thereby helping to make their communities a safer place.

GLOBE Mission Mosquito and GLOBE Observer are part of the international GLOBE program (www.globe.gov).

Learn more and download the free GLOBE Observer app at: observer.globe.gov

Citation: Burck, E. (2019). Beyond the Bite: GLOBE Mission Mosquito Disease Guide. Retrieved from *https://strategies.org/products/beyond-the-bite.*

NASA Partner

This document was developed by the Institute for Global Environmental Strategies under the NASA Earth Science Education Collaborative, which is supported by NASA under IGES award No. NNX16AE28A. Any opinions, findings, and conclusions or recommendations expressed in this material or are those of the authors and do not necessarily reflect the views of the National Aeronautics and Space Administration.

INSTITUTE for GLOBAL ENVIRONMENTAL STRATEGIES

Beyond the Bite:

GLOBE Mission Mosquito Disease Guide

GLOBE Observer

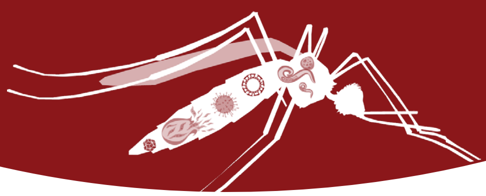


TABLE OF CONTENTS

BACKGROUND

The work that you are doing with the GLOBE Observer Mosquito Habitat Mapper (MHM) has direct implications for human health. Millions of people worldwide die from mosquito-borne diseases every year, while hundreds of millions more endure the symptoms.

The word “mosquito” is Spanish for “little fly.” While that may be an accurate description of its physical size, it directly contradicts the amount of misery the mosquito causes to the human species. Mosquitoes cause more human suffering than any other organism.

One of the goals of the GLOBE Mission Mosquito campaign is to build awareness of some of the most common mosquito-borne diseases. This guide, entitled “Beyond the Bite,” is designed to meet that goal. Part I offers guidelines for using this resource. Part II provides an introduction to the biology, pathology, and history of mosquito-borne diseases. Part III lists relevant vocabulary terms. Part IV begins with a “quick-reference” table, followed by individual entries on seven mosquito-borne diseases, including chikungunya, dengue, eastern equine encephalitis, malaria, West Nile virus, yellow fever, and Zika virus.

Mosquito Life Cycle

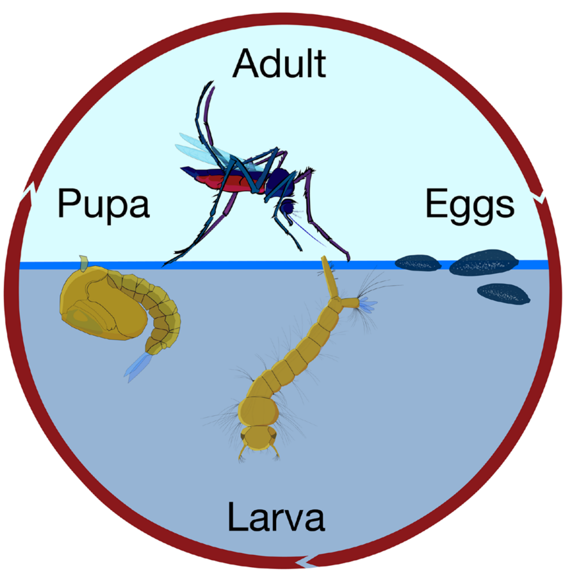


Figure 1. Mosquitoes go thorugh four distinct life stages: **egg, larva, pupa,** and **adult**. The time it takes for a mosquito egg to become an adult depends on environmental conditions such as temperature and resource availablitiy, and can range from as little as four days to over a month. Maturation typically takes about 8-12 days in the mid-latitudes.

Mosquito as Disease Vector

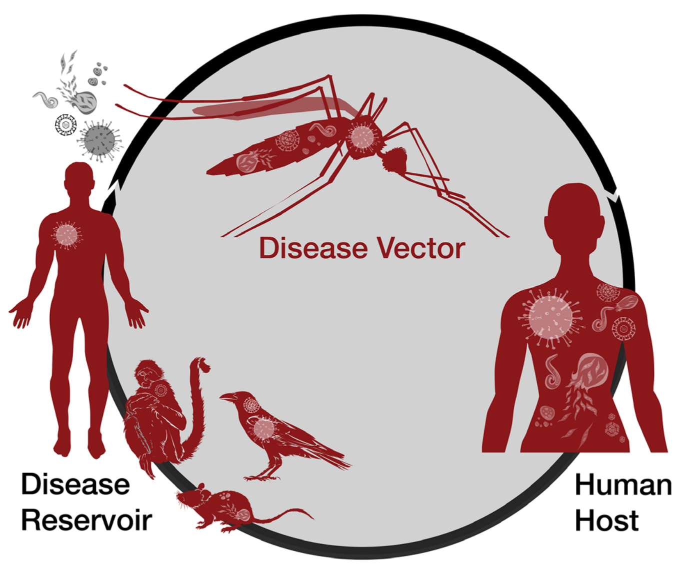


Figure 2. Mosquitoes are a **disease vector,** transferring a pathogen from a disease reservoir to a host. The **disease reservoir** is the habitat in which the pathogen normally lives, grows, and multiplies (such as a mammal or bird). A **pathogen** is a disease agent, such as a virus or microorganism, which can cause disease. A **host** is an organism in which a disease-causing pathogen lives and replicates.

Part I: User Guidelines

Commitment to any research investigation, whether affiliated with formal or informal education, relies on a personal foundation of passion, interest, and concern. Your passion and interest in being involved in this science-focused project are evident by your willingness to seek out mosquito habitats, examine them for mosquito larvae and pupae, identify them, eradicate them, and report your findings.

But why should you care about doing those things?

Because the organisms you are investigating are responsible for:

- transmitting diseases to human beings.
- transmitting diseases that can cause severe illness and death.
- spreading into geographic areas where they have not been seen before.
- affecting- and even altering- human history.

How deeply would you care and how passionately would you work to eradicate mosquitoes in your neighborhood if you knew the symptoms, effects, and impacts of the diseases that they might carry?

"Beyond the Bite" is designed as a reference guide to seven of those mosquito-borne diseases. It can be used in both formal and informal education settings. The targeted user is the citizen scientist. To insure user-friendliness and ease of accessibility, the content is concise, the format is standardized, and the style is informal. The introduction uses an engaging storyline approach. A vocabulary list, entitled, "Mosquito-lingo" introduces and defines relevant terms that are used throughout the guide. The disease section begins with a reference table, followed by separate standardized entries for each disease.

Recommendations for use:

"Beyond the Bite" can be used with audiences in both formal education and informal education (libraries, museums, afterschool programs, camps, scouts, etc.) settings.

Below are some recommendations for its use:

1. Print or open online to:

- introduce mosquito-borne diseases (the bump and itch are not the problem!).
- build the reason for "why" they should care about their MHM work.
- make connections between those mosquitoes identified in the field and the diseases they have been known to transmit.
- make global connections to the problems of mosquito-borne diseases.
- build a background in mosquito-borne diseases information prior to a lesson or presentation.

2. Use the information contained in the guide to:

- create a community awareness brochure/door-hanger for those mosquitoes in their area or the diseases reported in their area.
- write and/or make a public service announcement in their area.

- enhance a science fair project or a community service project.
- earn a scouting badge (e.g., Boy Scouts Insect Study merit badge or the Girl Scouts Think Like a Citizen Scientist Journey).

The guide is not a lesson and therefore does not align to NGSS, however ….

Both the ***Mosquito Habitat Mapper*** and **"Beyond the Bite"** are intended for use by citizen scientists; neither resource is specifically designed as a classroom lesson. Therefore, they are not aligned to the *Next Generation Science Standards* (NGSS).

However, the information contained in both is obviously rooted in the life sciences. Related topics are found in two of the NGSS Life Science (LS) Disciplinary Core Ideas (DCIs): **LS1 From Molecules to Organisms: Structures and Processes,** under both LS1A: Structure and Function and LS1B: Growth and Development of Organisms; and, **LS2 Ecosystems: Interactions, Energy, and Dynamics,** under both LS2A: Interdependent Relationships in Ecosystems, and LS2C: Ecosystem Dynamics, Function and Resilience. Because the spread of these diseases beyond the tropics in both northerly and southerly directions is being strongly influenced by global climate change, it should also be noted that this aspect of the resource is in the Earth and Space Science (ESS) domain in the DCI **ESS3 Earth and Human Activity** as component idea ESS3D: Global Climate Change.

In addition, the Mosquito Habitat Mapper and the "Beyond the Bite" disease guide reflect many of the practices used by professional scientists. These are listed in the *NGSS* as **Science and Engineering Practices (SEP)** and include: asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, constructing explanations and designing solutions, engaging in argument from evidence, and obtaining, evaluating, and communicating information. By their very nature, the MHM and disease guide also incorporate the *NGSS* **Crosscutting Concepts (CCC)** of patterns, cause and effect, structure and function, and stability and change in systems.

Part II: Introduction

The Story of Mosquito-borne Diseases

The story is an old one.

Many of the diseases transmitted by mosquitoes to humans have been around a very long time; the resulting human death toll is staggering. The annoying yet unassuming mosquito innocently flew among humans, appearing to only sneak small quantities of blood from them along the way.

But eventually this deception was uncovered. On August 20,1897, Sir Ronald Ross, a British medical doctor, established the link between mosquitoes and malaria after discovering the parasite that causes malaria in the stomach tissue of a female *Anopheles* mosquito. Three years later, in 1900, following the publication of a paper by Dr. Carlos Finlay, MD, of Cuba and the investigations of the U.S. Army Yellow Fever Commission under the direction of Major Walter Reed, MD, the mosquito was confirmed as the vector of yellow fever. Now in the spotlight, mosquitoes would become the antagonists in many disease stories. Humans had discovered who was responsible for transmitting some diseases (mosquitoes), as well as what was being transmitted (parasites and viruses). Since that time, we have determined how the pathogens are transmitted, why the victim gets sick, and when and where it is most likely to happen.

The conflict

Survival provokes conflict.

Mosquito survival depends on tracking down and stealing blood. The conflict with humans arises when the target is human blood.

Blood is not necessary for a mosquito's self-survival; mosquitoes get their nourishment from sugars found in plant nectar. Blood is necessary for the survival of the species. The eggs inside the female mosquito need proteins from blood for development. Those eggs will then give rise to the next generation of mosquitoes … and so on.

The conflict appears to end there. The mosquito bites the human to obtain species-sustaining blood, the human is annoyed and left with a bump and an itch. But there is more. The conflict is intensified by the occasional appearance of a third character. This third character is microscopic, operates covertly (hidden), and plays a sinister role that heightens the conflict.

This third character is a pathogen - in this case a virus or a protozoan - that can cause a disease. More information about the mosquito (playing the role of the vector), the human (playing the role of the victim), and the virus/protozoan (playing the role of the pathogen) follows below. All will then be interwoven into the story of each individual disease.

The Pathogen

The mosquito is not the pathogen; it is a pathogen delivery service (vector).

A pathogen can be a microorganism (such as a bacterium, fungus, or parasite) or an abiotic agent (such as a virus) that causes a disease. Six of the seven mosquito-borne diseases included in this guide are caused by viruses: chikungunya, dengue, eastern equine encephalitis, West Nile, yellow fever, and Zika. Only one of them, malaria, is caused by a type of parasite called a protozoan.

There are significant differences between viruses and protozoans. Viruses are made up of a piece of DNA or RNA wrapped in a protein coat. They do not reproduce on their own- they must get inside the cell of a host to be able to make copies of themselves. The host cell then breaks open to release the new viruses, thereby allowing the virus to spread to other cells in the host. Antivirals are not typically used to treat viruses. In most cases, the symptoms of virally caused diseases are treated with over-the-counter medications; in more severe cases, hospitalization may be required.

The protozoan is a single-celled organism with its DNA inside a nucleus. *Plasmodium*, the organism that causes malaria, is a genus of protozoans. Most drugs used in the treatment of malaria kill the *Plasmodium* while they are in the blood. Although concerted efforts to develop a malarial vaccine are ongoing, and administration of a promising new vaccine for children is underway in Africa, none is currently or widely available.

The Vector

She is just trying to be a good mosquito mother- not a harmful disease-causing insect.

A vector is an organism that transmits a disease from one organism to another. Some, but not all, mosquitoes are vectors; they pick up viruses and parasites and transmit them to humans, while rarely being affected by the pathogen themselves.

In the process, the female mosquito obtains the pathogen by biting an animal, often a bird, monkey, horse, rodent or human that already has it. Subsequently, in biting the next animal, she inadvertently leaves some of that pathogen behind. Only the female mosquito bites, but she is not looking for food (energy). All mosquitoes get their energy from eating plant nectar and sugars. The female is after specific proteins that are required for her eggs to develop properly and vital to the survival of the species. Those proteins are found in the blood.

Mosquitoes mate soon after emerging as adults. Each female mates only once while males mate several times. Females store sperm for the rest of their lives. The number of eggs that get fertilized depends on getting the specific blood proteins needed.

The Attack

She will find you and your blood using visual, olfactory, and thermal cues.

Female mosquitoes can find a blood meal source in three ways:

1. by observing movement and bright colors (in clothing) (5-15 meters away)
2. by smelling (olfaction) several odors associated with animals
   - carbon dioxide exhaled during breathing (10-15 meters away)
   - lactic acid released in perspiration
   - lotions/perfumes applied by humans
3. by sensing warmth (body heat) from warm-blooded animals (<1 meter)

Mosquitoes have no teeth. However, the female can use her long, sharply pointed, and serrated mouthpart called a proboscis to almost imperceptively penetrate the skin. Within the proboscis are several tubes. One tube immediately begins to pump saliva into the victim. The saliva contains both enzymes that act as painkillers and anticoagulants that keep the blood from clotting, but it may also include any viruses or parasites she has picked up. Another tube sucks in the victim's blood.

The Victim

The species that suffer the consequences are humans.

The human, from whom blood was taken, will first notice the effects at the bite site. The human body responds to the sudden appearance of "foreign" mosquito saliva by releasing a chemical called histamine. Histamine increases blood flow and white blood cell count around the site, which causes the inflammation (welt) and irritation.

If the saliva of the mosquito transfers viruses or parasites during the bite, the victim will begin to feel the effects of that particular pathogen within days (length of time varies by disease). For more on the symptoms and treatments, see the individual guides to the seven diseases.

Tracking the Vector

What keeps mosquitoes around; what keeps them away.

Mosquitoes thrive in areas with seasonal or year-round warm air temperatures, standing water, and forage plants. Additionally, females must have access to a blood meal in order to reproduce. Since many places on Earth meet these criteria, mosquitoes live - and spread disease - over much of our planet.

Many factors keep mosquitoes and the diseases they transmit around. These include:

- presence of standing water receptacles (decorative, functional or waste)
- climate change
- increased urbanization
- evolution of viruses
- increased international travel to endemic areas (for recreation, business or the military)
- unintentional transport of infected mosquitoes (in used tires, cut flowers, etc.)

To keep mosquitoes away and reduce the probability of contracting a disease, it is recommended that you do the following:

- stay away from areas of standing water
- get rid of unnecessary sources of standing water in your environment (follow Mosquito Habitat Mapper protocols)
- keep grass and bushes trimmed to decrease habitat area
- place screens on windows
- avoid wearing bright colors
- use insect repellent
- use bed nets

Part III: Mosquito-lingo

Terms found in this introduction or the individual disease guides

Alphavirus: a genus of single-stranded RNA viruses. Several species in this genus are responsible for human and animal diseases. An *Alphavirus* causes chikungunya.

Amplifying host: a living organism that, after acquiring a virus or parasite, develops a high enough internal levell of it for a mosquito to acquire it when biting.

Arbovirus: a general term for any virus transmitted by an arthropod. (The word arbovirus is an acronym for the arthropod-borne virus). Viruses in the genera *Alphavirus* (see above) and *Flavivirus* (see below) cause six of the seven diseases included in this guide.

Arthropod: an invertebrate animal in the Phylum Arthropoda. Members have an exoskeleton, a segmented body and paired jointed appendages ("arthro" meaning joint/"pod" meaning foot). Insects, such as mosquitoes, are arthropods. Arthropoda is the largest phylum in the Animal Kingdom.

Endemic: a disease that is regularly found in a particular locality or region.

Epidemic: an outbreak of a disease affecting many people in a particular area or at a specific time.

Epidemiology: the science that deals with the incidence, distribution, and control of diseases.

Flavivirus: a genus of single-stranded RNA viruses containing over 70 species, many of which are significant human pathogens. Dengue, West Nile, Zika, and yellow fever are mosquito-borne diseases caused by *Flaviviruses.*

Genera: plural form of the word genus. Genus is the taxonomic category above species.

Pandemic: an epidemic of disease that has spread across a large region, such as multiple continents, or even worldwide.

Parasite: An agent that lives in or on a host. Viruses and *Plasmodium* are parasites that can live in the mosquito. After being transferred to humans, they can live in the human body.

Pathogen: an agent (virus, bacteria, protozoa) that causes a disease.

Plasmodium: a genus of protozoans (unicellular microorganisms). The genus contains ~170 species, five of which cause malaria: *P. falciparum, P. malariae, P. vivax, P. ovale,* and *P. knowlesi.*

Reservoir host: a living organism that hosts a pathogen and thereby serves as a source of infection.

Sub-Saharan: the region of Africa south of the Sahara Desert.

Subtropics: geographic and climate zones located north of the Tropic of Cancer to ~40°N latitude; in the southern hemisphere, located south of the Tropic of Capricorn to ~40°S latitude.

Tropics: geographic and climate region of Earth around the equator- extending north to the Tropic of Cancer (23.5°N) and south to the Tropic of Capricorn (23.5°S)

Vector: an organism (such as a mosquito) that transmits a pathogen.

Beyond the Bite: Mosquito-borne diseases

AT A GLANCE

DISEASE NAME	PATHOGEN Cause of disease	VECTOR Mosquito genus (genera) transmitting the pathogen	RANGE
CHIKUNGUNYA	Virus	*Aedes*	Worldwide
DENGUE	Virus	*Aedes*	Southeast Asia, Pacific Islands, Middle East, Africa, North America, Central America, and South America
EASTERN EQUINE ENCEPHALITIS	Virus	*Aedes* *Coquillettidia* *Culex*	Eastern coastal areas of North America, Central America, and South America
MALARIA	*Plasmodium* (protozoan parasite)	*Anopheles*	Tropical/subtropical areas of Africa, Southern Asia, Central America, and South America
WEST NILE VIRUS	Virus	*Culex*	Worldwide
YELLOW FEVER	Virus	*Aedes*	Tropical and subtropical areas of Africa, Central America, and South America
ZIKA VIRUS	Virus	*Aedes*	Tropical and subtropical areas of Africa, Southeast Asia, the Pacific Islands, North America, Central America, South America

SYMPTOMS	TREATMENT
Joint pain, fever, headache, muscle pain, joint swelling, rash, vomiting, nausea, chills	No vaccine Rest, fluids, over-the-counter medications
High fever, vomiting, muscle/joint pain, aching bones, skin rash, severe headache, eye pain	No vaccine Rest, fluids, over-the-counter medications Possible hospitalization
Possibly no symptoms Fever, chills, vomiting, body aches, joint pain Complications: encephalitis, seizures, paralysis, coma - leading to death	No vaccine Rest, fluids, over-the-counter medications Possible hospitalization
Fever, chills, headache, muscle pain, nausea Complications: seizures, coma, kidney/liver failure - leading to death	Vaccines in testing Antimalarial drugs
Possibly no symptoms Fever, headache, body ache, joint pains, vomiting, diarrhea, rash Complications: encephalitis and/or meningitis - leading to death	No vaccine Rest, fluids, over-the-counter medications Hospitalization if brain/spinal cord is affected
Possibly no symptoms Fever, chills, headache, back pain, body aches, nausea, weakness Complications: liver damage with jaundice - leading to death	Vaccine Antiviral drugs Rest, fluids, over-the-counter medications
Possibly no symptoms Rash, fever, red eyes, joint pain Infection can pass to fetus causing preterm birth, miscarriage, and birth defects (microcephaly)	No vaccine Rest, fluids, over-the-counter medications

Chikungunya

Vital Point: *Aedes aegypti*, the principal mosquito species that transmits the chikungunya virus, has several breeding and behavioral quirks that make it extremely difficult to control. Experts describe *Aedes aegypti* as opportunistic, demonstrating a remarkable adaptability to changing environments, which is influenced by the way humans inhabit the planet. (Source: WHO).

Cause: Chikungunya is caused by a virus, which is classified in the genus *Alphavirus*.

Mosquito Vectors: *Aedes aegypti* and *Aedes albopictus* transmit the chikungunya virus.

Range: Worldwide. Chikungunya originated in Africa and is emerging as a global threat. It is common in Africa, Asia, Europe, the Caribbean, and the Indo-Pacific regions. Cases have been reported in the U.S. territories of Puerto Rico, Virgin Islands, Samoa and Guam. Imported cases amongst travelers returning from regions of infection have also been reported in 23 U.S. states.

Transmission: Non-human primates serve as the principal reservoir host for the virus between human outbreaks. There is evidence that rodents, birds and small mammals may also serve as reservoirs. *Aedes aegypti* mosquitoes, biting during the day, transmit the chikungunya virus.

Incidence (rate or frequency): Chikungunya is pandemic with roughly 150,000 confirmed cases reported in 2016. In the United States, there are fewer than 1000 cases/year.

Symptoms: Appear 3-7 days after the infections. The most common symptom is joint pain; however other symptoms include sudden onset of fever (lasting about one week), headache, muscle pain, joint swelling, rash, vomiting, nausea, and chills. Death from chikungunya is rare, with a mortality rate of 0.1%.

Treatment: No vaccine is currently available, but some are in clinical trials. Rest, fluids and over-the-counter medicines are recommended for symptom relief. People who have had chikungunya once are likely to be protected from future infections via an acquired immunity.

General Information: The disease derives its name from a local language in southeast Tanzania and northern Mozambique and means, “that which bends up.” The reference is to the human victim’s stooped posture caused by joint pains.

History: The disease was first detected in 1952 in southern Tanzania; the virus was identified one year later. The first significant urban outbreak occurred in the 1960’s in Bangkok. Epidemics have since occurred in Africa and Asia. The first case reported in the western hemisphere was in the Caribbean in late 2013. Chikungunya was first identified in U.S. travelers returning from affected regions in 2014.

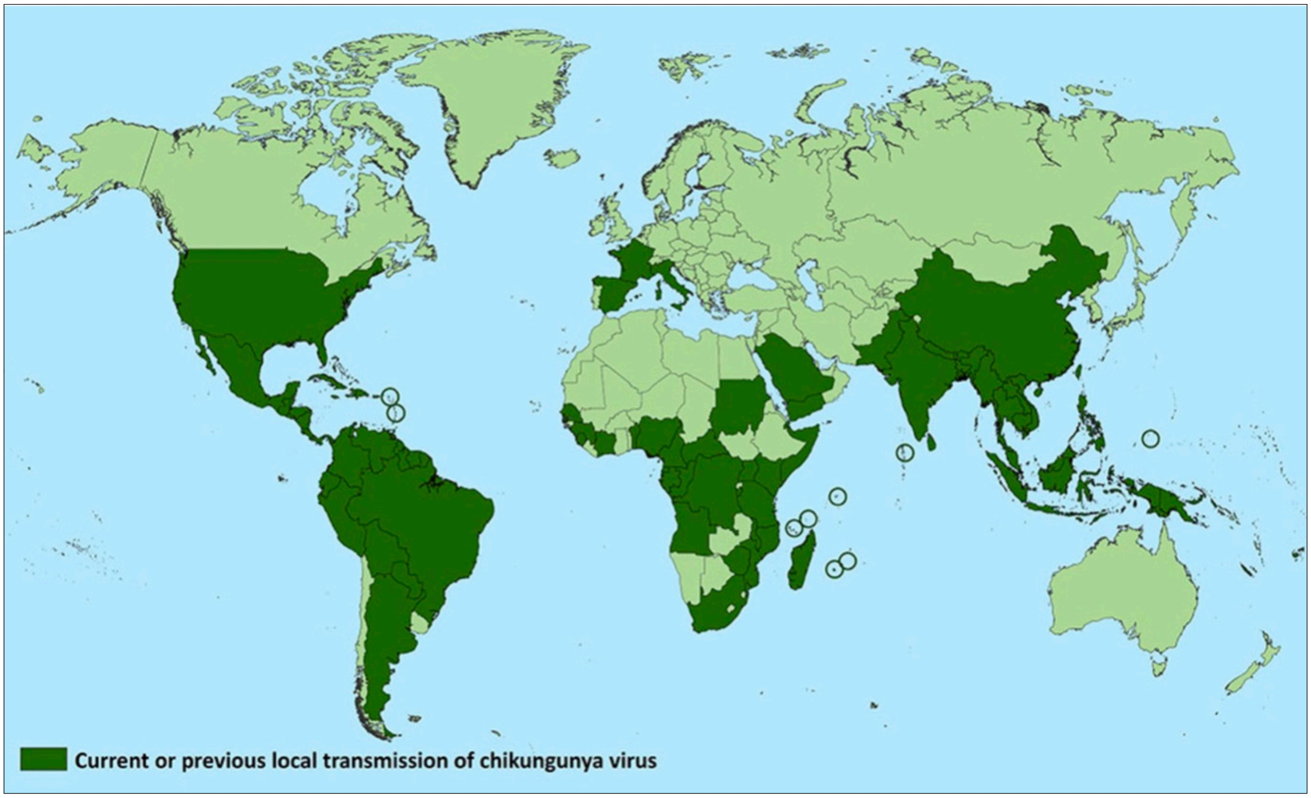


Figure 1. Countries and territories where chikungunya cases have been reported (as of May 29, 2018). Source: CDC. *https://www.cdc.gov/chikungunya/geo/index.html.* See also interactive map for chikungunya transmission: http://ais.paho.org/phip/viz/ed_*chikungunya_amro.asp*

Resources

This video aims to disseminate knowledge about mosquitoes of the species *Aedes aegypti*, *Aedes albopictus* and *Aedes polynesiensis* by presenting these arthropods as vectors for yellow fever, dengue, Zika and chikungunya viruses, which in recent years have caused serious public health problems:

- **Knowing the mosquitoes of Aedes:** Transmitters of arboviruses *https://youtu.be/InIEvefMW5Y*
- **Conociendo los mosquitos Aedes***:* Ransmisores de arbovirus *https://youtu.be/jpNFe3l2h3A*
- **Conhecendo os mosquitos Aedes**: Transmissores de arbovírus *https://youtu.be/3tiuRHuzST4*

Dengue

GLOBE Observer

Vital Point: The worldwide incidence of dengue has risen 30-fold in the past 30 years, and more countries are reporting their first outbreaks of the disease. More of these outbreaks are explosive in ways that severely disrupt societies and drain economies (Source: WHO).

Cause: Dengue is caused by a virus. The virus is classified in the genus *Flavivirus*.

Mosquito Vectors: *Aedes aegypti* (primarily) and *Aedes albopictus* transmit dengue.

Range: Nearly 40% of the world's population live in areas at risk for dengue. It is endemic in more than 100 countries throughout the South East Asia/Pacific, the Americas, the Middle East, and Africa. Dengue is common in the U.S. territories of American Samoa, Puerto Rico, Guam, and the U.S. Virgin Islands. Local dengue outbreaks have occurred in Hawaii, Florida, and Texas over the past ten years.

Transmission: A mosquito transmits the dengue virus from one person to another. A mosquito can pick up the dengue virus when she bites a person who already has it in their blood. She can then pass the virus to another human during a subsequent bite.

Incidence (rate or frequency): The prevalence of dengue has grown dramatically in recent decades. Before 1970, only nine countries had experienced severe dengue epidemics. The World Health Organization (WHO) now reports an estimated 390 million dengue infections per year; 96 million of those infected seek medical care. The vast majority of cases are asymptomatic; therefore, the actual numbers of dengue cases are underreported or misclassified. Severe dengue was first recognized in the 1950's during dengue epidemics in the Philippines and Thailand. Today, severe dengue affects most Asian and Latin American countries and has become a leading cause of hospitalization and death among children and adults in these regions. However, early detection and access to medical care have lowered fatality rates below 1% in some areas.

Symptoms: The viral incubation period is 3-14 days. Symptoms usually show up within two weeks of infection. Symptoms include sudden onset of high fever, vomiting, muscle/joint pain, aching bones, skin rash, severe headaches, and eye pain. Symptoms generally last 3-10 days. The severe form of dengue, also called dengue hemorrhagic fever, can cause severe bleeding and a sudden drop in blood pressure (shock). Dengue hemorrhagic fever is a leading cause of severe illness and death among children in some Asian and Latin American countries.

Treatment: While no vaccine is currently available, one experimental vaccine has recently received limited FDA approval. Others are in development and clinical trials. Symptoms may be relieved with rest, fluids and over-the-counter fever and pain medications.

General Information: Dengue is considered the world's most important mosquito-borne viral disease due to its range and impact on human health. The disease is referred to by two other names: dengue fever- due to its classic onset symptom of high fever, and breakbone fever- because of its associated body aches.

History: The first recognized dengue epidemics occurred almost simultaneously in Asia, Africa, and North America in the 1780's. The first confirmed case was reported by Benjamin Rush in 1789, who coined dengue's common name, "breakbone fever." Epidemics have occurred periodically in the Western Hemisphere for more than 200 years. Since World War II there has been an increase in the transmission due to population movements and cargo transportation. The frequency of dengue epidemics has increased dramatically in most tropical countries in the American region.

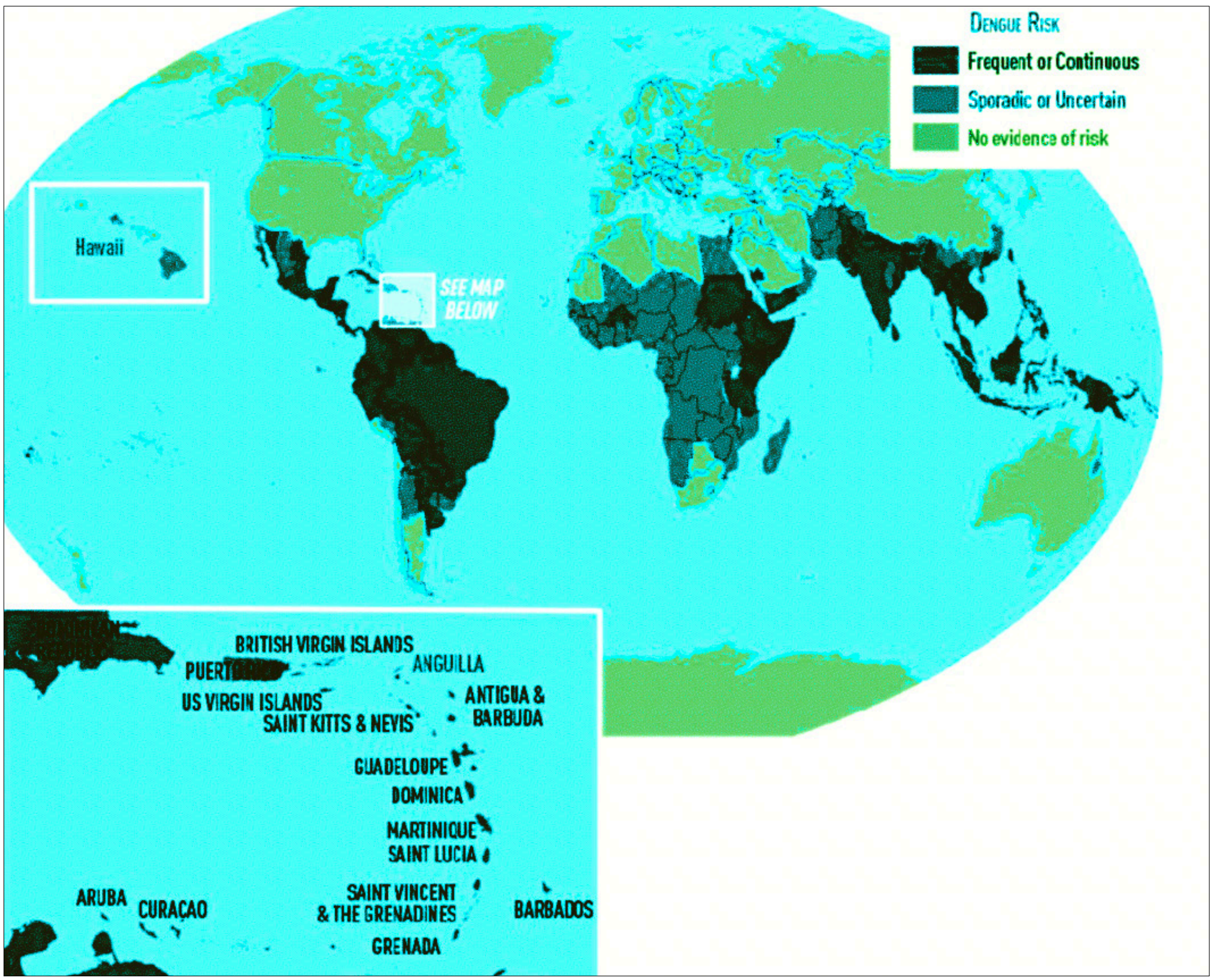


Figure 1. World risk map for dengue. Frequent or continuous risk = either frequent outbreaks occur, or transmission is ongoing. Sporadic or uncertain risk=risk varies and is unpredictable, and that country-level data is not available. Source: CDC. Downloaded from: *https://www.cdc.gov/dengue/areaswithrisk/around-the-world.html*

Resources

This video aims to disseminate knowledge about mosquitoes of the species *Aedes aegypti*, *Aedes albopictus* and *Aedes polynesiensis* by presenting these arthropods as vectors for yellow fever, dengue, Zika and chikungunya viruses, which in recent years have caused serious public health problems:

- **Knowing the mosquitoes of Aedes:** Transmitters of arboviruses *https://youtu.be/InIEvefMW5Y*
- **Conociendo los mosquitos Aedes***:* Ransmisores de arbovirus *https://youtu.be/jpNFe3l2h3A*
- **Conhecendo os mosquitos Aedes**: Transmissores de arbovírus *https://youtu.be/3tiuRHuzST4*

Eastern Equine Encephalitis (EEE)

Vital Point: In 1933, many horses living in the eastern coastal areas of Delaware, Maryland, New Jersey, and Virginia experienced a sudden viral-induced brain inflammation that resulted in 75 deaths. The name eastern equine encephalitis derived from that outbreak: the disease occurred in the eastern United States, affected horses ("equine" referring to members of the genus Equus- which includes horses), and resulted in encephalitis (the medical term for inflammation of the brain). This same virus also infects humans.

Cause: Eastern equine encephalitis (EEE) is caused by a virus. The virus, named eastern equine encephalitis virus (EEEV), is classified in the genus *Alphavirus*.

Mosquito Vectors: Mosquitoes in three different genera are known to transmit the eastern equine encephalitis virus to humans and mammals. Those genera include *Aedes, Culex,* and *Coquillettidia.*

Range: EEE affects eastern coastal areas in North America, Central American and South America. Outbreaks have also occurred in the Great Lakes region and the Caribbean. Most cases in the United States are in the Atlantic and Gulf Coast states.

Transmission: The virus is often found in mosquitoes that tend to live in or near freshwater swamps containing hardwood trees. Female mosquitoes attain the virus from biting several host species of area birds such as jays, blackbirds, warblers, finches and sparrows. The mosquito can then transmit the virus to a human or to a horse. The disease is not spread from horse-to-horse or human-to-human as both are considered dead-end hosts (the virus does not reach high enough concentrations in the bloodstream of a horse or human to infect a mosquito).

Incidence (rate or frequency): Human cases of EEE are rare. In the United States, there are generally between 5 and 15 cases reported annually. However, in 2019 the number of U.S. cases reported was much higher, reaching nearly 30 by September 25. The states that tend to report the most cases each year include Florida, Massachusetts, New York, North Carolina and Michigan.

While EEE is fairly rare, it continues to be the domestic arboviral (virus transmitted by a mosquito) disease with the highest fatality rate. Approximately 35% of those who acquire the virus and develop encephalitis will die as a result.

People over the age of 50, under the age of 15, and individuals who are immune-compromised are at greatest risk of severe illness or death from EEE.

Symptoms: While some people never develop symptoms of EEE following the bite of the infected mosquito, those that do will experience a sudden onset of fever, chills, body aches and joint pain within three to ten days. Typically, symptoms subside after one to two weeks and recovery is complete. However, an EEE infection can lead to encephalitis (a swelling of the brain) that may result in seizures, paralysis, coma, and death. Those who survive this advanced stage are often left with disabling mental and physical problems.

Diagnosis of EEE is done by testing the blood or spinal fluid for antibodies against the virus.

Treatment: There is no specific vaccine, treatment or cure for eastern equine encephalitis. If EEE is suspected, the patient should be evaluated by a healthcare provider. Hospitalization is required for those with a severe EEE infection. People who have had EEE once are likely to be protected from future infections via an acquired immunity.

General Information: Often, the first indication that the EEE virus is actively being transmitted in an area is the diagnosis of the disease within the horse population. Horses sustain a high mortality rate from this disease. While there is no EEE vaccine for humans, there is one available for horses; owners are encouraged to vaccinate.

Although outbreaks of EEE do not occur every year, those living in the eastern states where EEE is a threat during summer months should stay informed. Up-to-date risk and outbreak information is provided through state government websites such as the Department of Public Health or through local media. (For example, in September 2019, the State of Massachusetts declared both “Critical” risk levels and “High” risk levels in several areas of the state after ten human cases were reported. The situation made national news.)

History: The 1930s were a pivotal time in our understanding of the pathogen, vector, and transmission of eastern equine encephalitis. Although the virus itself may have been around much earlier, it was the 1933 outbreak of encephalitis in horses in the eastern United States that aroused concern about the pathogen. One year later, mosquitoes were identified as potential carriers of that virus. In 1935, researchers investigating another outbreak suspected birds as a possible reservoir host, which was later confirmed. Then, in 1938, an outbreak of encephalitis in the northeastern United States left 30 children dead. Medical examinations that followed confirmed those deaths as the first human cases of EEE.

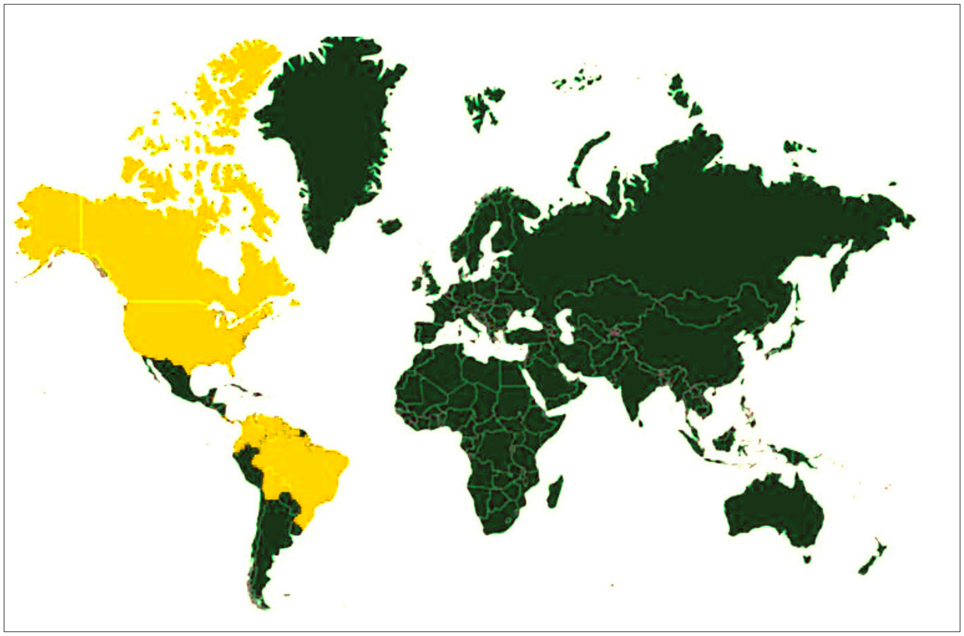


Figure 1. Disease distribution map of eastern equine encephalitis showing incidence of the disease; countries with history of infections/serological evidence are marked in yellow (if any region within a country reported EEE, the entire country was highlighted). Source: Manuja, Balvinder & Manuja, Anju & Gulati, BR & Virmani, Nitin & Tripathi, Bhupendra N.. (2018). Zoonotic Viral Diseases of Equines and Their Impact on Human and Animal Health. The Open Virology Journal, 12, 80-98. *https://openvirologyjournal.com/VOLUME/12/PAGE/80/FULLTEXT/* Used under CC BY 4.0 / Map color changed.

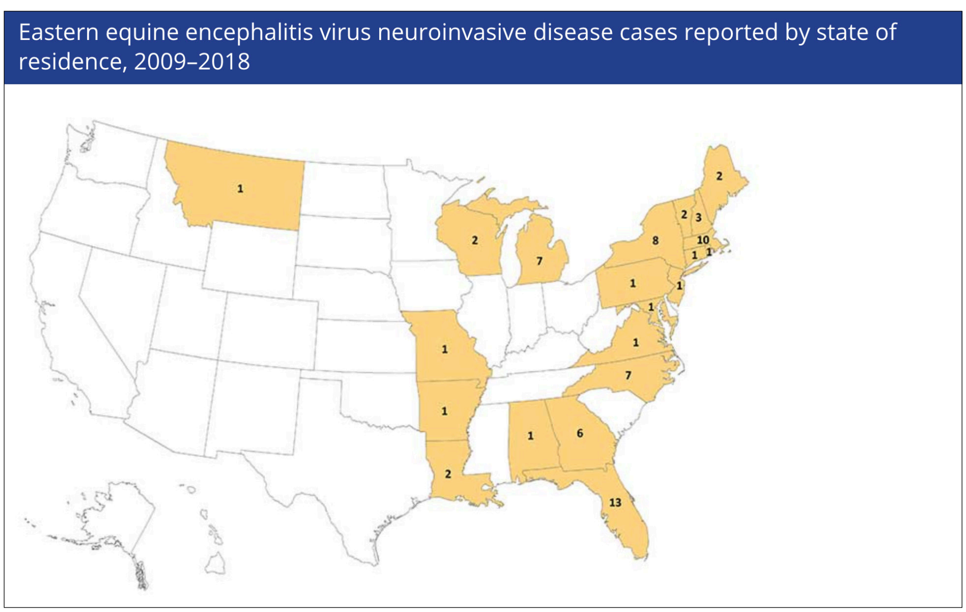
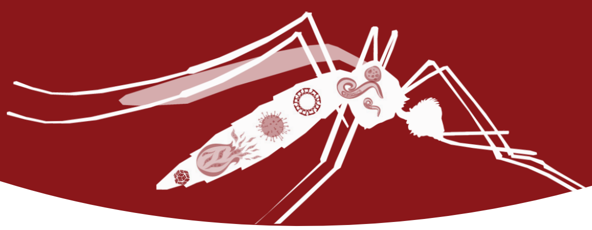


Figure 2. United States map showing number of EEE cases by state from 2009-2018. Screenshot from: *https://www.cdc.gov/easternequineencephalitis/tech/epi.html#casesbyyear*

Malaria



Vital Point: World Malaria Day is commemorated every year on April 25. Established in 2007, it focuses global efforts to educate people on the disease, its prevention, and control. Globally, 3.3 billion people in 106 countries are at risk of malaria. The disease is preventable and curable (Source: WHO).

Cause: Malaria is caused by a unicellular parasite in the genus *Plasmodium*. As a parasite, it must derive its food by living on or in a host organism (which includes both mosquito and human). There are five species of *Plasmodium* known to cause malaria in humans including *P. falciparum, P. malariae, P. vivax, P. ovale,* and *P. knowlesi.* Of these, *P. falciparum* is both the most prevalent malaria vector in Africa, and the most deadly.

Mosquito Vectors: There are approximately 40-50 species of *Anopheles* mosquitoes that are capable of transmitting *Plasmodium* parasites to humans (see Figure 1).

Range: Malaria is common in tropical and subtropical areas of Africa, Southern Asia, Central America, and South America. While the disease has had significant impacts in the United States in the past, it is now considered rare. However, competent *Anopheles* vectors are established in many areas of the United States – so the reintroduction of malaria into the United States is a persistent risk.

Transmission: The mosquito acquires the *Plasmodium* parasite by ingesting blood from an infected human. Once inside the mosquito, the parasites reproduce and develop. When that mosquito bites a human, the parasites contained in the salivary gland are injected into the person's blood. When the human is infected, the *Plasmodium* parasite first grows and multiplies in the liver. The new *Plasmodium* cells leave the liver and move into red blood cells, where they continue to increase. The cycle continues when additional mosquitoes acquire the parasite from biting an infected host.

The primary tool for preventing mosquito-to-human transmission is the use of insecticide-treated bed nets. Bed nets provide essential protection from malaria because the Anopheles mosquito bites during the night, from dusk to dawn.

Incidence (rate or frequency): According to WHO's 2018 World malaria report, in 2017 there were 219 million cases reported worldwide and 435,000 deaths (one every 1.2 minutes-mostly children in Africa). The highest incidence is concentrated in sub-Saharan Africa and in Papua New Guinea. Malaria is rare in the United States; the roughly 1,700 cases reported annually are usually associated with travelers or immigrants returning from sub-Saharan Africa and South Asia. The highest risk of death from malaria is among children aged 5 and under.

Symptoms: When *Plasmodium* parasites enter the human body, they first travel to the liver, where they reproduce. Disease symptoms occur when *Plasmodium* are released into the host's red blood cells, generally 10-15 days after the infective mosquito bite. Early symptoms include high fever, chills, headache, muscle pain, and nausea. If untreated, the continued destruction of red blood cells and the subsequent clogging of small blood vessels can lead to more severe complications such as seizures, coma, kidney or liver failure, anemia, and hypoglycemia (low blood sugar), any of which can result in death.

Treatment: In April, 2019 the World Health Organization announced that, after successful clinical trials, a promising new malaria vaccine for young children will be introduced in selected areas of Africa *(https://www.who.int/malaria/publications/atoz/first-malaria-vaccine/en/).* For those who are diagnosed with malaria, treatment primarily involves the use of antimalarial drugs. It is worth noting that the *Plasmodium* parasite has become increasingly drug-resistant. Early diagnosis and prompt treatment are critical. If untreated, two species of the malaria-causing *Plasmodium (P. ovale* and *P. vivax)* can remain dormant in the human liver and cause a disease relapse weeks or even years later. After repeated bouts of malaria, a person can develop an acquired protective immunity which does not provide complete protection but does reduce the risk of severe disease following subsequent exposure to *Plasmodium*. Numerous children die in Africa due to low acquired immunity and lack of treatment.

General Information: The word malaria *(mal aria)* means "bad air," a reference to the common belief, dating from the 13th century, that the disease was spread by unhealthy air (*miasma*). Malaria is one of the world's major public health problems. In Africa, the large number of cases impacts the continent's finances, with estimated costs for medical care and related expenses totaling $12 billion per year.

Malaria has been found in people who do not live in areas of high incidence and who have not traveled abroad. The term "airport malaria" has been coined in reference to malaria cases caused by infected mosquitoes transported by aircraft from countries where malaria is endemic to non-endemic countries, where "hitchhiking" mosquitoes then transmit the pathogen to a local host.

History: There is evidence from ancient societies of China, Egypt, Greece, and India, demonstrating that malaria has had an impact throughout human history. An epidemic in Rome, Italy in 79 AD devastated the area, subsequently Roman soldiers and merchants carried malaria north to England and Denmark. *Plasmodium* was repeatedly introduced into the Americas through the slave trade between the 16th-19th centuries. By 1750, malaria was present from New England to the Mississippi Valley. During the Civil War (1861-65), malaria killed hundreds of soldiers. Malaria traveled west to California during the gold rush, claiming the lives of Native Americans along the way.

In 1906, the construction of the Panama Canal in Central America was nearly halted due to the high number of cases among workers. In the 1930's, malaria affected 30% of the population in the Tennessee Valley region. That percentage declined when the Tennessee Valley Authority brought hydroelectric power to the south. The improved land management and flood control reduced the area of potential mosquito breeding sites. During World War

II, many soldiers died of malaria in training bases in the southern United States and in the Pacific campaign.

The Center for Disease Control (CDC) was initially founded as the Office of Malaria Control in War Areas (MCWA) on July 1, 1946, to eradicate malaria in the southern United States, especially around the military bases. In 1951 the United States officially proclaimed that malaria was eradicated. Malaria remains a problem in many areas of the world, none more so than Africa.

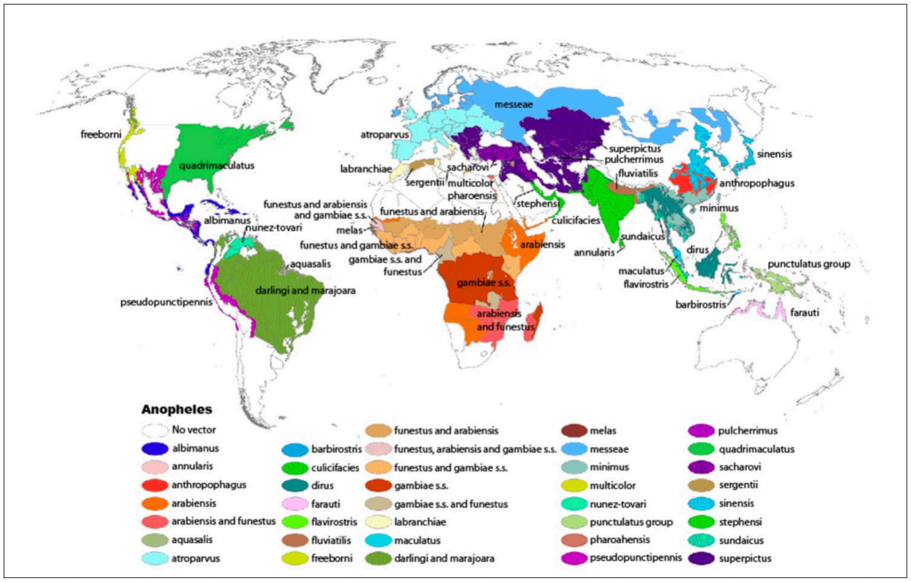


Figure. 1. Global distribution of dominant or potentially important malaria vectors. Source: *Kiszewksi et al., 2004. American Journal of Tropical Medicine and Hygiene 70(5):486-498. Downloaded from https://www.cdc.gov/malaria/about/biology/mosquitoes/map.html*

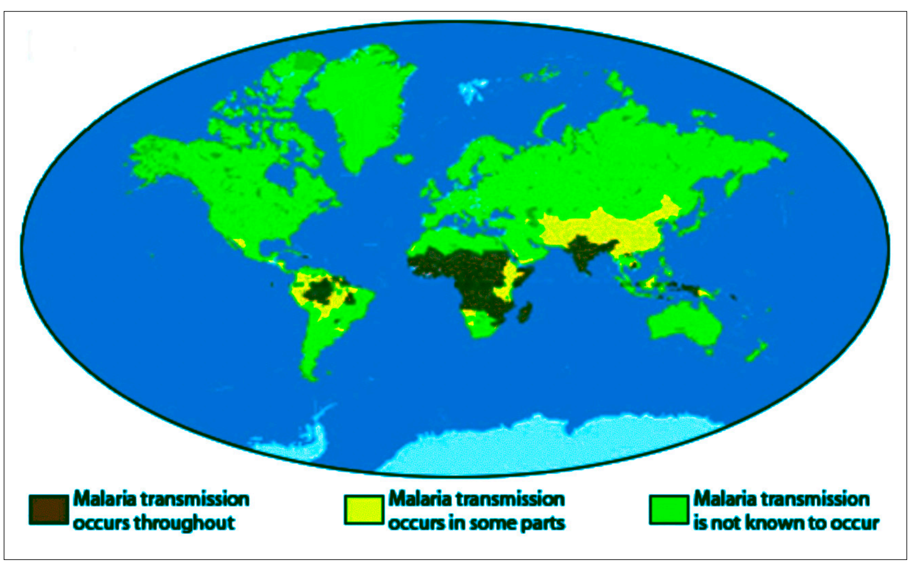
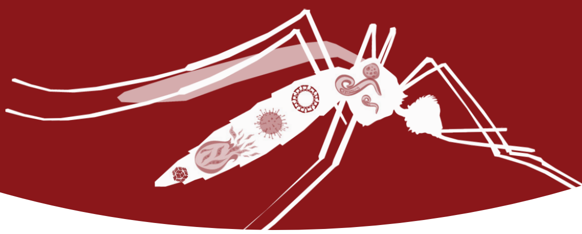


Figure. 2. Global distribution of malaria. Where malaria is found depends primarily on climatic factors such as temperature, humidity, and rainfall. Source: CDC. *https://www.cdc.gov/malaria/about/distribution.html*

West Nile Virus



Vital Point: Mosquitoes, humans, birds, horses and other animals are all hosts for West Nile virus (WNV) or play a role in the transmission of this virus. Birds are the most common reservoir hosts. Mosquitoes acquire the virus from birds and subsequently then transfer it to humans, horses, and other mammals. Vaccines are available for horses but not yet for humans (Source: WHO).

Cause: West Nile virus is caused by a virus. The virus is classified in the genus *Flavivirus*.

Mosquito Vectors: Over 65 species of *Culex* mosquitoes are known to host the West Nile virus. Some of the common species that can both host and transmit WNV include *C. tarsalis, C. pipens, C. quinquefasciatus, C. stigmatosoma, C. thriambus, Cx. coronator,* and *C. nigripalpus.*

Range: Currently, WNV has a pandemic distribution, including all of Africa, and parts of Europe, Middle East, West Asia, and Australia. Since its introduction in 1999 into North America, the virus has spread and become widely established from Canada through the United States to Central and South America.

Transmission: Birds are the natural hosts of the virus. Mosquitoes acquire the virus when they extract blood from infected birds and subsequently transmit the virus from one bird to another. This is the natural cycle. Certain *Culex* species can feed on both birds and humans. The virus eventually infiltrates the mosquito's salivary glands; then it is released into a human during a mosquito bite, completing the bird to mosquito to human transmission. Humans, horses and other mammals are considered "dead-end" hosts – none of them can develop high enough levels of the virus in their blood for mosquitoes to pick up during a bite. Birds are called an "amplifier" host - they develop levels of the virus high enough for mosquitoes to acquire and transfer. *Culex* mosquitoes tend to bite from dusk to dawn.

Incidence (rate or frequency): In 2012 the United States had its first WNV epidemic that resulted in the death of 286 people. WNV is the leading domestically acquired mosquito-borne disease in the United States and is now considered the mosquito-borne disease of most concern. In 2018, case numbers were unusually high in Nebraska, California, North Dakota, Illinois, and South Dakota. In that same year in Europe the number of cases exceeded the total from the previous seven years combined.

Symptoms: The viral incubation period is usually 3-14 days. Diagnosis is difficult with eight out of ten victims (80%) showing no symptoms. If present, symptoms include fever, headache, body ache, joint pains, vomiting, diarrhea, and rash. One in 150 will develop severe encephalitis (inflammation of the brain), and/or meningitis (inflammation of the membranes surrounding the brain/spinal cord). Effects on the brain and spinal cord may be permanent; one out of ten affected neurologically will die.

Treatment: There is neither a vaccine nor a specific treatment for WNV. Over-the-counter medicines can be used to relieve some symptoms. Hospitalization is required when the brain and/or spinal cord are involved.

General Information: The disease derives from the West Nile District in Uganda. Outbreaks often occur along major migratory routes of birds with several species of birds carrying the virus. Some birds, such as crows and jays, can die from WNV. Reporting dead birds and having them examined for WNV is one way to check for the presence of WNV in the environment. West Nile virus can also infect horses and other mammals.

History: WNV was first discovered in 1937 in the blood of a woman from the West Nile District of Uganda. The virus was identified in birds in the Nile delta regions in 1953. The mode of arrival into the U.S. in 1999 is still unresolved; however, West Nile virus may have come from an infected bird or by an infected mosquito brought in through shipping ports.

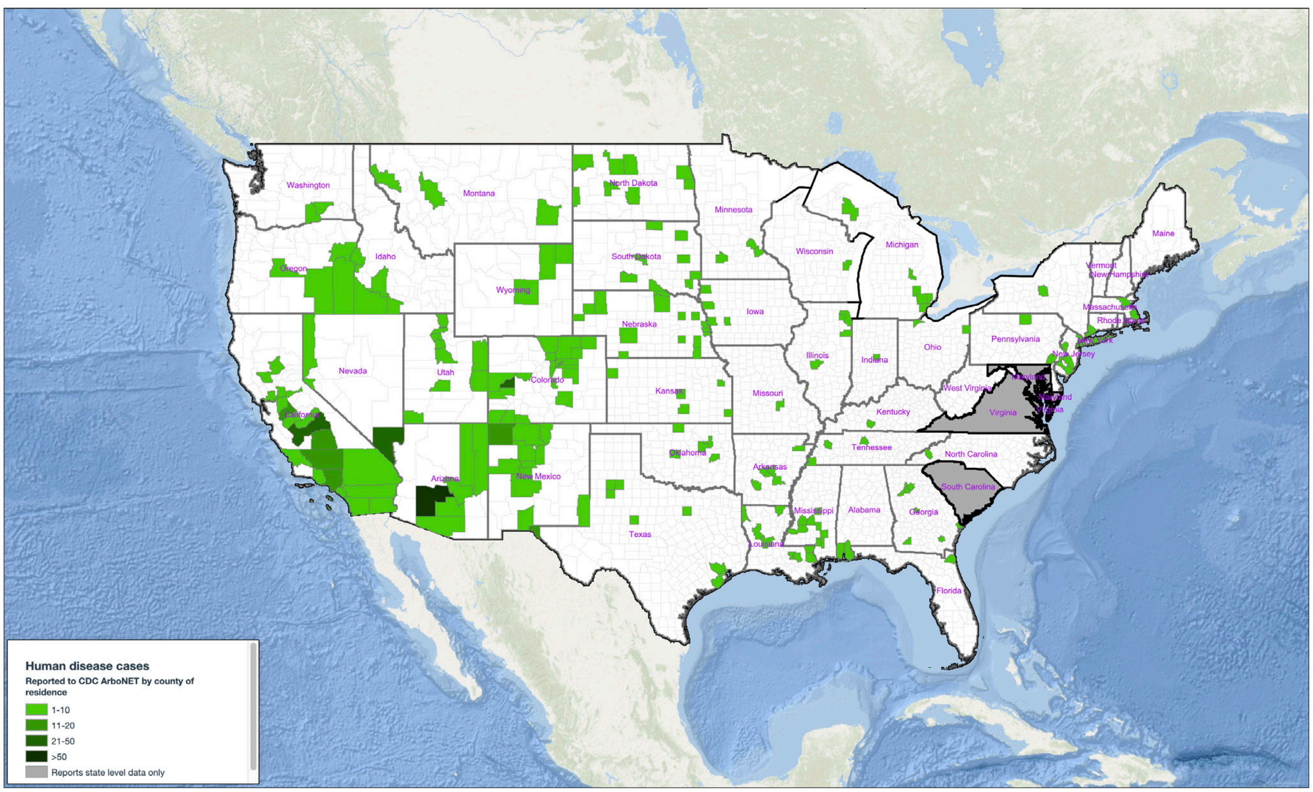
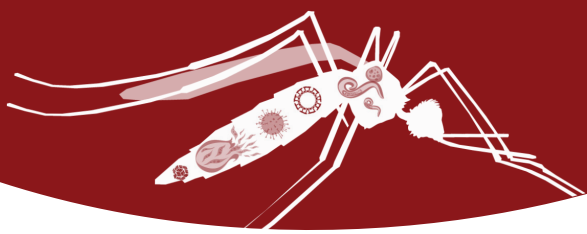


Figure 1. Human WNV disease cases, 2019. (CDC). Screenshot from: *https://wwwn.cdc.gov/arbonet/Maps/ADB_Diseases_Map/index.html*

Yellow Fever

GLOBE Observer



Vital Point: Yellow fever circulates in three distinct transmission cycles, responding to different environments and involving different vectors and hosts: 1) Jungle: non-human primates, such as vervets and monkeys living in tropical rainforests are the primary reservoir of yellow fever. They are bitten by mosquitoes that then pass the virus to other non-human primates. Humans working or traveling in the forest can also be bitten and can develop yellow fever; 2) Intermediate (ecotone): semi-domestic mosquitoes bite both non-human primates and people (the most common type of outbreak in Africa); and, 3) Urban: infected mosquitoes transmit the virus from person to person in densely populated areas with high mosquito density. (Source: WHO)

Cause: Yellow fever is caused by a virus. The virus is classified in the genus *Flavivirus*.

Mosquito Vectors: *Aedes aegypti, Aedes albopictus* (urban and intermediate transmission cycle) transmit yellow fever.

Range: Yellow fever is common in the tropical and subtropical areas of Africa, Central America, and South America.

Transmission: Mosquitoes acquire the virus by feeding on infected non-human primates or infected humans. The infected mosquito then transfers the virus to another non-human primate or human through subsequent bites.

Incidence (rate or frequency): Ninety percent of all yellow fever cases occur in Africa. Worldwide, there are 200,000 infections per year and 20,000-30,000 deaths each year. The disease is not actively transmitted in the United States.

Symptoms: Most infections are asymptomatic. If mild symptoms develop, they usually occur 3-6 days after infection. Symptoms may include a sudden onset of fever, chills, severe headache, back pain, body aches, nausea, vomiting, fatigue, weakness, and loss of appetite. Symptoms typically disappear within five days. Fifteen percent of the infections develop with serious complications that can be fatal. If fever returns, the patient enters the toxic phase, which involves liver damage. It is during this phase that the victim may exhibit jaundice, a yellowing of the skin and eyes from which the disease name derives. Half of the patients who enter the toxic phase die within 7-10 days.

Treatment: A very effective vaccine is available; one dose provides sustained immunity and life-long protection. Antiviral treatments are available for the disease itself. Rest, fluids, pain relievers, and fever-reducers are recommended.

General Information: A safe, effective, and inexpensive vaccine for yellow fever has been around for over 80 years. It is a single dose of an avirulent form of the virus. It is recommended for people aged nine months and older and for those traveling to or living in areas of risk. The vaccine may be required for entry into certain countries and should be administered at least 10 days before travel.

History: Yellow fever has been present in tropical countries since the1400's but little was known about how it was transmitted. Epidemics of the disease were greatly feared; they were unpredictable and often catastrophic with the death rate reportedly as high as 85%. In 1880, a Cuban physician, Dr. Carlos Finlay, proposed that mosquitoes might be responsible. In 1900, U.S. Army infectious disease physicians Major Walter Reed, Aristides Agramont, Jesse Lazear, and James Carroll confirmed that mosquitoes were the vectors for yellow fever.

Reaching that conclusion involved human subject testing; team member James Lazear volunteered to be experimentally bitten by mosquitoes that had fed on sick patients and died days later from the disease. In 1901, the remaining members of the team determined that a virus was the cause of yellow fever; the discovery of the first human virus. In 1936, Max Theiler and his colleagues developed an attenuated (weakened yellow fever virus) vaccine; their work was rewarded with the Nobel Prize in 1951.

Although yellow fever is not a current threat in the United States, the disease has had a historical impact. The first U.S. outbreak occurred in the late 1690's. An epidemic struck Charleston, South Carolina in 1732, where deaths occurred so frequently that the usual ringing of bells to mark a death was forbidden. In the summer of 1793, refugees from a yellow fever epidemic in the Caribbean fled to Philadelphia, Pennsylvania, at the time the largest city and capital of the United States. By October of that year the daily death toll reached 100.

Eventually, a cold front moved in and killed the mosquitoes, but not before 5,000 people had died. Caring for victims caused such a strain on public services that the city government collapsed. In 1878, yellow fever killed more than 13,000 people in the lower Mississippi Valley, one of the worst medical disasters in U.S. history. During the construction of the Panama Canal, yellow fever deaths were so devastating to the French workforce that it influenced that country's decision to abandon their efforts and turn the project rights over to the United States.

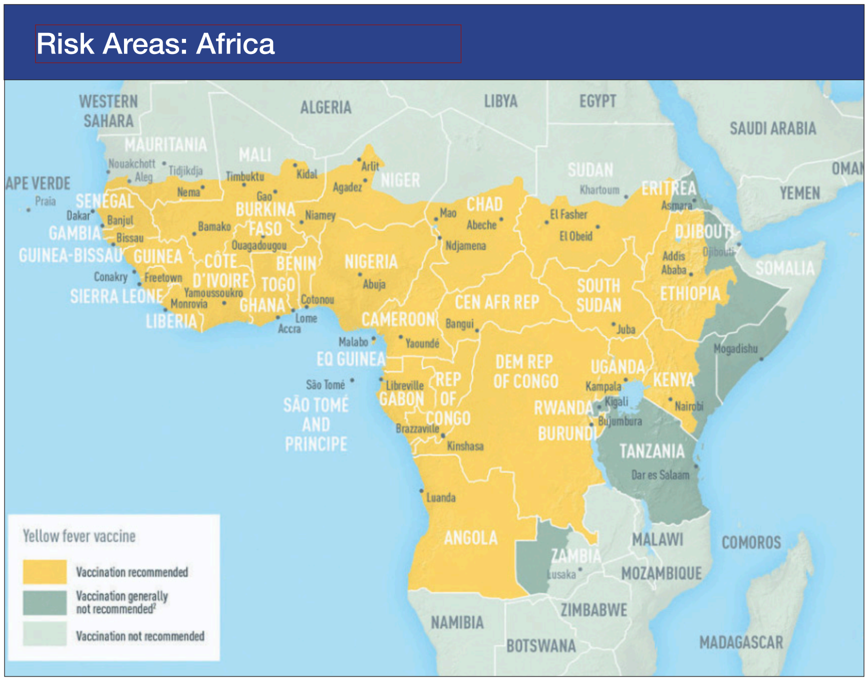


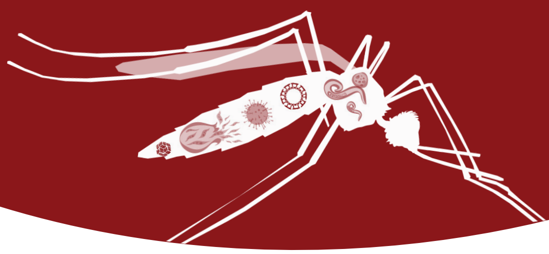
Figure 1 and 2. Risk areas of Yellow Fever in Africa (left) and South Amercia (right). Source: CDC. Screenshot from *https://www.cdc.gov/yellowfever/maps/*

Resources

This video aims to disseminate knowledge about mosquitoes of the species *Aedes aegypti*, *Aedes albopictus* and *Aedes polynesiensis* by presenting these arthropods as vectors for yellow fever, dengue, Zika and chikungunya viruses, which in recent years have caused serious public health problems:

- **Knowing the mosquitoes of Aedes:** Transmitters of arboviruses *https://youtu.be/InIEvefMW5Y*
- **Conociendo los mosquitos Aedes***:* Ransmisores de arbovirus *https://youtu.be/jpNFe3l2h3A*
- **Conhecendo os mosquitos Aedes**: Transmissores de arbovírus *https://youtu.be/3tiuRHuzST4*

Zika



Vital Point: The 2015-2016 outbreak of Zika in Brazil demonstrated how a previously obscure and mild mosquito-borne disease can become a global health emergency. The possibility that a mosquito bite during pregnancy could be linked to severe birth defects in newborns has alarmed the public and astonished scientists. (Source: WHO)

Cause: Zika is casued by a virus. The virus is classified in the genus *Flavivirus.*

Mosquito Vectors: *Aedes aegypti* (primary), *Aedes albopictus, Aedes polynesiensis* transmit Zika.

Range: More than 90 countries have reported cases of Zika. *Aedes aegypti* and *A. albopictus* mosquitoes originated in warm tropical climates of Africa, SE Asia, and the Pacific Islands. In the United States, both of these mosquito species are invasive and have been migrating northwards.

Transmission: Zika virus can be transmitted to humans through two pathways: (1) from mosquito to human and, (2) from one human to another. In addition to blood, the virus is found in human urine, saliva, semen, and amniotic fluid. Because it is found in semen, the virus can be transmitted directly from human to human during sexual intercourse, even when the infected person is asymptomatic. The virus can be passed from mother to fetus through amniotic fluid. For this reason, pregnant women are warned not to travel to areas experiencing Zika outbreaks.

Incidence (rate or frequency): Within the last decade, the Zika virus has risen from relative obscurity to become an international public health concern. In 2016-17, between 500,000 and 1.5 million suspected cases were reported worldwide, with a related 4300 related cases of microcephaly in infants born of mothers infected with Zika. During that same time, there were 5168 cases reported in the United States. Of those, most (4897) were reported in individuals who had traveled to areas with Zika outbreaks. Some (224) locally transmitted cases were reported in Texas and Florida. Forty-seven cases were determined to have been sexually transmitted.

Symptoms: Most people (80%) who contract the Zika virus do not develop symptoms. For those that do, the most common symptom is a rash, with or without a fever, that lasts from 2-7 days. Other symptoms include red eyes and joint pain. It is important to note that a Zika infection in a mother during pregnancy can transfer to the fetus, even if she presents no symptoms. This can potentially cause preterm birth, miscarriage or serious birth defects, including microcephaly (small head size).

Treatment: No vaccine currently exists, however one or more are in development. No specific treatment is available, but symptoms may be relieved by rest, fluid, and over-the-counter medications for fever and pain.

General Information: The disease is named after the Zika Forest in Uganda, the site where the virus was first discovered. The disease itself is usually mild; however, the concern lies in the harm that the virus can cause to the fetus when the mother is infected during pregnancy. Currently, a person's travel history is a significant factor in the chances of getting the Zika virus. It is highly recommended that pregnant women or women planning to become pregnant avoid traveling to areas with Zika outbreaks. It is also recommended that anyone returning from an outbreak area make a conscious effort to avoid getting mosquito bites for three weeks by:

- staying indoors,
- wear clothing that covers exposed skin,
- use repellants, and
- use condoms during sexual intercourse to protect against sexual transmission.

History: The Zika virus was first identified in monkeys in Uganda in 1947 and was first identified in humans in 1952 in Uganda and Tanzania. The first recorded outbreak of the disease was reported in Micronesia in 2007. In March 2015, a Zika outbreak in Brazil was followed by a noticeable increase in microcephaly among newborns, leading scientists to establish a causal connection.

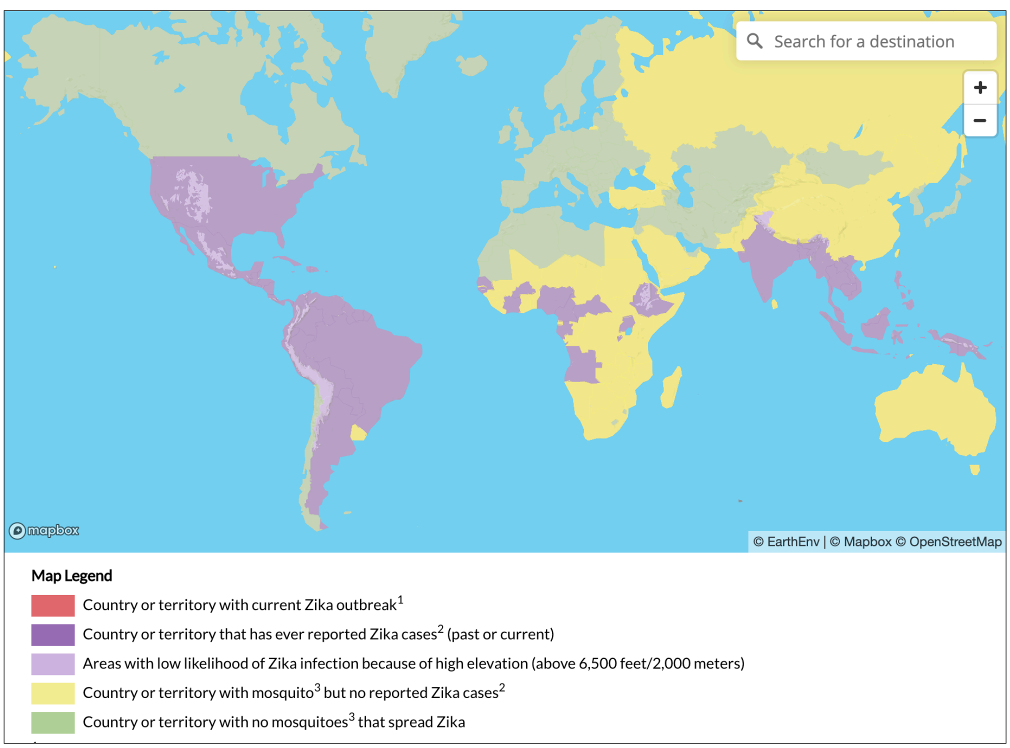


Figure 1: World map showing passt and present Zika cases along with presence or absence of Zika-transmitting mosquitoes. Screenshot from: *https://wwwnc.cdc.gov/travel/page/zika-travel-information*

Resources

This video aims to disseminate knowledge about mosquitoes of the species *Aedes aegypti*, *Aedes albopictus* and *Aedes polynesiensis* by presenting these arthropods as the vectors for yellow fever, dengue, Zika and chikungunya viruses, which in recent years have caused serious public health problems:

- **Knowing the mosquitoes of Aedes:** Transmitters of arboviruses *https://youtu.be/lnIEvefMW5Y*
- **Conociendo los mosquitos Aedes***:* Ransmisores de arbovirus *https://youtu.be/jpNFe3l2h3A*
- **Conhecendo os mosquitos Aedes**: Transmissores de arbovírus *https://youtu.be/3tiuRHuzST4*

Resources & Acknowledgements

The Resources

The resources below were consulted in the creation of this guide. Use them to find additional information on mosquito-borne diseases.

- Centers for Disease Control (CDC) *https://www.cdc.gov/DiseasesConditions/*
- EarthSky *https://earthsky.org/earth/how-mosquitoes-find-you-to-bite-you*
- PBS: How Mosquitoes Use Six Needles to Suck Your Blood | Deep Look *https://www.youtube.com/watch?v=rD8SmacBUcU&feature=youtu.be*
- World Health Organization (WHO) *https://www.who.int/health-topics/*

The following videos were created by the Oswaldo Cruz / Fiocruz Institute's Image Production and Treatment Service to disseminate knowledge about *Aedes aegypti, Aedes albopictus* and *Aedes polynesiensis* mosquitoes and referenced in *Beyond the Bite: Dengue.*

Acknowledgements

Written by **Elizabeth Burck,** Senior Science Educator, Institute for Global Environmental Strategies

Design, cover illustration, and graphics by **Jenn Paul Glaser,** Science Illustrator, Scribe Arts for Our Planet, Oceans and Fisheries

Reviewers and Contributors

Dr. Ryan Carney • Assistant Professor of Digital Science • Department of Integrative Biology, University of South Florida

Renee Codsi • University of Washington School of Public Health • Center for One Health Research

Dr. Trena Ferrell • Earth Science Division Education and Public Outreach Lead • NASA Goddard Space Flight Center

Kimberly A. Foss • Entomologist • Northeast Massachusetts Mosquito Control and Wetlands Management District

Dr. Caio França • Assistant Professor • Department of Biology, Southern Nazarene University

Dr. Michael Jabot • Professor • Science Education/Director, Institute for Research in Science Teaching • The State University of New York at Fredonia

Dorian Janney • ADNET/GSFC/NASA • Senior NASA Earth Science Education and Communications Specialist

Dr. Russanne Low • Senior Earth Scientist and Science Lead for NASA GLOBE Observer Mosquito Habitat Mapper • Institute for Global Environmental Strategies

Phil Maytubby • Director of Public Health Protection • OKC-County Health Department

Theresa Schwerin • Vice President for Education and Principal Investigator, NASA Earth Science Education Collaborative • Institute for Global Environmental Strategies

Cassie Soeffing • Senior Science Educator • Institute for Global Environmental Strategies

Dr. William J. Soeffing • Chairperson of Natural Science Academic Area/Professor of Biology • University of Sioux Falls.

Dr. Mike Wimberly • Professor • Department of Geography and Environmental Sustainability • University of Oklahoma

INSTITUTE *for* GLOBAL ENVIRONMENTAL STRATEGIES

BEYOND THE BITE

GLOBE Mission Mosquito Disease Guide · 2019

Download at: *https://strategies.org/products/beyond-the-bite*