

Fever Pitch

Mosquito-Borne Dengue Fever Threat Spreading in the Americas

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Acknowledgments

The authors would like to thank Zev Ross and Hollie Kitson of ZevRoss Spatial Analysis, Ithaca, New York, for conducting the mapping, and to Sashti Balasundaram for dengue case data research. Dr. Chester G. Moore of Colorado State University generously provided access to mosquito occurrence data. We would also like to thank Cindy and Alan Horn for their support of NRDC's Global Warming and Health Project.

We are grateful to the following peer reviewers who provided invaluable comments on this report: Chester Moore, Colorado State University; Kristie L. Ebi, ESS, LLC; Joan Brunkard, U.S. Centers for Disease Control and Prevention; Mary Hayden, National Center for Atmospheric Research Institute for the Study of Society and Environment.

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Available at www.nrdc.org/health/dengue

Executive Summary

Over the past decades, several infectious diseases have increased in incidence and expanded into new geographic areas. There are multiple factors that contribute to the spread of disease, including increasing urban population density, more international travel, and widespread international import/export of goods. Global warming threatens to further exacerbate the spread of many infectious diseases because increases in heat, precipitation, and humidity can foster better conditions for tropical and subtropical insects to survive and thrive in places previously inhospitable to those diseases. A new NRDC analysis finds that two types of mosquitoes capable of transmitting dengue fever can now be found across at least 28 states. As temperatures rise, the potential for transmission of this dangerous disease may increase in vulnerable parts of the United States.

We already know inevitable climate change impacts are projected for the next 50 to 100 years. Investing now in enhanced environmental monitoring and improved health reporting can help us understand the relative contribution of factors (both related and unrelated to climate) influencing infectious diseases and strengthen our climate-health preparedness, both now and for the future.

Dengue Fever Is On the Rise

Dengue (or “breakbone”) fever is high on the list of mosquito-borne diseases that may worsen with global warming. The symptoms of the disease include high fever, rash, and severe headache with aching bones, joints, and muscles. Dengue and its deadly complications, dengue hemorrhagic fever and dengue shock syndrome, have increased over the past several decades. Increasing urbanization and population growth facilitate disease transmission, and for communities without reliable piped municipal water services, the need to collect and store household water in containers can provide the perfect habitat for mosquitoes to breed. More rapid international travel and trade can move viruses and mosquitoes from one part of the globe to another, increasing epidemic risks.

Researchers have projected that in the future, global warming could substantially increase the number of people at risk of dengue epidemics, as warmer temperatures and changing rainfall conditions expand both the area suitable for the mosquito vectors and the length of the dengue transmission season in temperate areas.

Currently, dengue fever and its complications cause an estimated 50 to 100 million infections, a half-million hospitalizations, and 22,000 deaths annually in more than 100 countries, including parts of South America, Central America, the Caribbean, India, Southeast Asia, and Africa. Dengue has increased 30-fold in the last 50 years.¹ By 2085,

an estimated 5.2 billion people—3 billion additional people worldwide—are projected to be at risk for dengue because of climate change–induced increases in humidity that contribute to increased mosquito presence.²

To date, outbreaks of locally transmitted dengue fever in the 50 United States have been limited to the Mexican border region and Hawaii. However, a new NRDC analysis identifies regions of the United States where multiple factors could result in increased vulnerability to dengue fever. Our analysis also shows that dengue fever (both imported and locally transmitted) has increased substantially since the 1970s in many parts of South and Central America, the Caribbean, and the United States, rising to more than 900,000 cases in the Americas in 2007. The number of dengue hemorrhagic fever cases soared to more than 26,000 by 2007. Epidemic outbreaks during 2007 in Brazil, Mexico, Honduras, Paraguay, Costa Rica, Bolivia, and Guyana affected hundreds of thousands.

By 2007, 488 “imported cases” in travelers returning to the United States were reported to the Pan-American Health Association; imported cases of dengue fever have now occurred in nearly every state in the nation. Nearly 4,000 cases of imported and locally transmitted dengue were reported to the U.S. Centers for Disease Control and Prevention between 1995 and 2005. When cases in the Texas-Mexico border region are included, the number rises to 10,000.

At the same time, the specific types of mosquitoes that can transmit dengue fever have become established in a swath of at least 28 states and the District of Columbia, and across the south and mid-Atlantic regions, creating a recipe for local transmission of the disease in the United States. An estimated 173.5 million Americans live in counties with one or both of the mosquito species that can transmit dengue fever.

Recommendations to Help Limit the Spread of Dengue Fever

Clinicians, local health officials, and the public need to be aware of dengue’s dangers and take the following steps to help limit its spread:

- Improve environmental monitoring**
 Mosquito trapping, geographic information systems (GIS) mapping, and remote sensing tools can help detect and track the occurrence and spread of dengue’s vector species, their habitat areas, and the presence of the dengue virus in mosquitoes. Ongoing research is also needed because global warming’s effects on temperature and rainfall patterns can affect the risks of dengue outbreaks differently in specific areas.
- Support better health surveillance**
 Dengue should be made a nationally notifiable disease throughout the United States, as it now is in Texas and Arizona. A surveillance system should be established for collection and timely virologic testing and analysis of blood samples from suspected dengue cases. Better education of clinicians and health departments is essential to help recognize dengue infections and treat them immediately. Consistent, centrally reported and confirmed dengue case surveillance data—with enhanced international coordination, data sharing, lab capacity, and outbreak notification among nations that share border communities, like the United States and Mexico—are needed to better understand the changing incidence of the disease and evaluate control programs.



The *Aedes aegypti* mosquito, shown here with larvae, is one transmitter of dengue fever.

Avoiding Dengue Fever When You Travel

To help protect yourself and your family, be sure to arm yourself with the latest information on where, when, and how dengue

infections can spread, especially if you plan to travel to parts of the world where dengue is already a public health problem. Travelers can reduce their risks by sleeping in well-screened or air-conditioned hotels, most of which also strive to keep their facilities free of waste containers that can hold shallow standing water and harbor immature mosquitoes. Travelers should also apply an insect repellent with 20–30 percent DEET on exposed skin, particularly in the morning and early evening hours, and wear loose, long-sleeved shirts and long pants. Before traveling, you should find out what parts of the world are currently experiencing dengue outbreaks by visiting the Centers for Disease Control and Prevention (CDC) or World Health Organization (WHO) websites for information.

- **Improve mosquito control**

Pest management that targets larval mosquito reduction should be implemented at a community level. Emptying, cleaning, treating, or removing stagnant water containers—including waste tires—is an important step that will help prevent transmission of dengue and other diseases such as West Nile virus. After storms, floods, and hurricanes, federal assistance for emergency vector surveillance and control should be made available immediately to affected localities.

- **Help create climate- and disease-resilient homes and communities**

Government programs to upgrade housing and municipal services will help reduce community vulnerability to dengue. Intact window and door screens, for example, can significantly reduce transmission of mosquito-borne disease. Access to dependable piped water and trash collection will further reduce mosquito breeding habitat and improve the overall health status of community residents. When storms, hurricanes, or floods damage homes, timely response efforts can help reduce infectious disease risks.

- **Reduce global warming pollution to decrease the extent and severity of warming**

Because climate change may expand the geographic range of dengue's mosquito vectors, addressing global warming at its source could help limit dengue and other climate-health risks. In that regard, governments should enact mandatory legislation to reduce global warming pollution and combat climate change. In addition, governments must act to protect communities from the impacts of climate change already underway.

- **Provide information for travelers visiting high-risk dengue areas**

The CDC has estimated that as many as 1 in 1,000 travelers to dengue-endemic countries become ill. See the sidebar on page v for information about symptoms to look for when traveling to vulnerable areas.

Dengue Symptoms to Watch For

If you travel to areas with dengue, symptoms to watch for include the “dengue triad” of:



- + High fever and chills
- + Severe pain (headaches; eye pain; bone, joint, and muscle pain)
- + Rash on the arms, legs, and torso, with redness and swelling of the hands and feet

An estimated 173.5 million Americans live in counties with one or both of the mosquito species that can transmit dengue fever.

CHAPTER 1

Dengue Fever Makes a Comeback in the Americas

Dengue (“breakbone”) fever is a globally reemerging viral disease transmitted to humans by the bite of an infected mosquito. Dengue and its complications cause an estimated 50 to 100 million infections, a half-million hospitalizations, and 22,000 deaths each year. Once considered predominantly a tropical illness, the disease has spread into more temperate areas, and its incidence has increased 30-fold in the last 50 years.³ Because of the speed of its spread, its increasingly serious complications, and the overwhelming burden of illness and death it causes, many consider dengue the world’s most important insect-transmitted viral disease.

Dengue has now been reported in more than 100 countries, especially in densely populated urban and residential areas. Recent epidemics have affected hundreds of thousands of people in Brazil and other parts of South America, the Caribbean, Southeast Asia, and India. Estimates suggest that 2.5 billion people—nearly 40 percent of the world’s population—live in areas where the disease can be acquired from local mosquitoes.⁴

Global warming is likely to increase the number of people at risk of dengue epidemics by expanding both the area suitable for the mosquito vectors and the length of dengue transmission season in temperate areas.⁵ By 2085, an estimated 5.2 billion people—more than 3 billion additional people worldwide—are projected to be at risk for dengue because of climate change–induced increases in humidity that contribute to the disease’s spread, based on models that use observed relationships between weather patterns and dengue outbreaks.⁶ Researchers in Australia and New Zealand calculated that climate change is projected to increase the range and risk of dengue in these countries. According to their study, another 1.4 million Australians could be living in areas suitable for the dengue mosquito vector by 2050. Moreover, the number of months suitable for transmission may rise, increasing the costs of dengue management three- to fivefold.⁷

In the United States, dengue fever outbreaks have so far been limited to the U.S.-Mexico border region and Hawaii. However, our analysis reveals that global warming could result in increased vulnerability to dengue fever throughout the United States and the Americas. The findings are cause for concern: The analysis shows an increase in dengue fever in recent years in the United States and its neighbors to the south. And the mosquitoes that can transmit this disease have become established in a swath of at least 28 states, making disease transmission more likely.

Classic Dengue Fever, Dengue Hemorrhagic Fever, and Dengue Shock Syndrome

Dengue fever (DF) is caused by a member of the same family of viruses that cause yellow fever, West Nile, and Japanese encephalitis. It is possible to become infected by dengue multiple times because the virus has four different serotypes.

Although each infection confers lifelong immunity to that particular serotype, a subsequent infection with a different serotype increases the risk of contracting the much deadlier form known as dengue hemorrhagic fever (DHF). The symptoms of dengue fever include high fever, rash, and a severe headache (the “dengue triad”). Additional symptoms include severe joint and muscle pain (hence the nickname “breakbone fever”), nausea, vomiting, and eye pain. Although dengue fever itself is rarely fatal, it can be an extraordinarily painful and disabling illness and may become epidemic in a population following the introduction of a new serotype.

Dengue hemorrhagic fever is a life-threatening illness that occurs in around 1 percent of dengue infections. DHF is characterized initially by a fever lasting up to a week, followed by bleeding gums and nose and internal bleeding. If not treated quickly, a life-threatening loss of blood can result, leading to dengue shock syndrome (DSS), internal bleeding, organ failure, and death. For people unable to get aggressive treatment, DHF fatality rates can range up to 20 percent. The WHO estimates that a half-million hospitalizations each year result from DHF, most of these among children. Prior to 1970, only nine countries had experienced DHF epidemics, but by 1995 that number had increased more than fourfold. In the Americas in 2007 alone, there were 26,000 reported cases of DHF, most of them in Mexico, Venezuela, Colombia, Honduras, and Brazil.⁸

Dengue is one of the costliest diseases to treat in developing countries.⁹ Treatment includes fluids, blood transfusions for DHF, and electrolyte therapy for DSS.¹⁰ There is no vaccine to protect against or medicine to cure dengue. The CDC estimates that an effective dengue vaccine may not be available for five to 10 years.¹¹ The prevailing method of dengue control is to combat the mosquitoes that spread the disease.

Surveillance for cases of dengue infection is underfunded, and there are widespread concerns that dengue infections are already underreported, both domestically and internationally.¹² Even in the United States, the suspected dengue numbers reported by the CDC represent “a minimum estimate of the actual number of U.S. travelers with dengue fever or its complication, DHF or DSS.”¹³ Because dengue is not a nationally notifiable disease in the United States, diagnostic samples are not routinely taken nor sent for

testing to CDC labs, and many cases may never be counted. Two different blood serum samples taken one to two weeks apart are needed to confirm a diagnosis of dengue, and important patient information about recent travel and medical history are not always available to ship along with serum specimens.¹⁴ Better dengue case surveillance is needed in order to have a full accounting of the extent of dengue’s impact on public health in the United States and around the world.

Global warming could increase the number of people at risk of dengue outbreaks by expanding both the area suitable for the mosquito vectors and the length of dengue transmission season in temperate areas.

Mosquitoes and Dengue Fever

Dengue is transmitted by mosquitoes. In a human, the virus incubates for three to 14 days before symptoms appear, with an average symptom onset at four to seven days. Other mosquitoes can bite an infected person and subsequently transmit the virus to uninfected people. In this way, the mosquito is acting as a “vector” to transmit the dengue virus from person to person.

According to the CDC, there are two species of mosquito that can transmit dengue fever.¹⁵ Both species are now found in parts of the United States (see Figure 4). The principal vector of dengue is *Aedes aegypti*, which is also the vector of yellow fever. *A. aegypti* is an aggressive biter (especially in early morning and late afternoon) that prefers to live inside buildings and feed on humans. It favors dark, indoor areas (closets, bathrooms, behind curtains, and under beds) but can also be found outdoors in gardens and in shallow standing water. *A. aegypti* is well established in much of the tropical and subtropical world, including the southeastern United States, but currently cannot survive winter temperatures in colder, northern states. *A. aegypti* has proliferated as the developing world has urbanized. Its domestic subspecies has become perfectly adapted to living in close contact with humans.¹⁶ *A. aegypti* is currently found in at least 16 U.S. eastern, southeastern, and southwestern states.

The potential for dengue fever transmission in the United States has increased since the late 1980s with the introduction of a second mosquito species, *Aedes albopictus*, the Asian Tiger mosquito. This mosquito was first found in the United States in Houston, Texas, in 1985; it is suspected to have arrived in shipments of used tires, which collect and hold rainwater and provide insulation from heat and cold, making them ideal mosquito breeding habitat.¹⁷ *A. albopictus* can tolerate colder temperatures, which has helped the Asian Tiger move into more than a thousand U.S. counties since its arrival. Unlike *A.*

aegypti, the Asian Tiger prefers suburban and rural settings and feeds on both humans and animals. The rapid spread of this species has raised concerns among public health officials because it is a potential carrier of dengue and other viral diseases and is likely to expand its population into other states.¹⁸

The Global Warming Connection

Among the complex set of factors influencing dengue transmission, global warming is particularly important because it can create warmer and wetter conditions that increase the risk of infection. Warmer temperatures boost the speed of development of adult mosquitoes, increasing their numbers. Female mosquitoes bite more frequently in hotter temperatures, and warmer winters enable mosquitoes to survive in areas that were formerly too cold. Higher temperatures also shorten the time it takes for the virus inside the mosquito to develop and become infective. This means that the mosquitoes become dangerous to humans more rapidly. Several studies have shown that in certain regions where dengue is present, vector abundance and disease incidence rise measurably with increases in temperature, precipitation, and humidity.¹⁹

Global warming is projected to increase the amount and variability of precipitation in many areas, which can create expanded habitat hospitable to immature mosquitoes. Higher humidity contributes to improved survival of eggs and adult mosquitoes. Drought can also lead to increased transmission in cities without adequate water and sanitation, because people store drinking water in containers that can serve as mosquito breeding sites. Finally, global warming can enhance the frequency and intensity of extreme weather events that are likely to disrupt shelter, water, sewer, and sanitation services. If window and door screens are damaged, human-mosquito contact will increase; if drinking water supplies are disrupted, people will be forced to store water in containers, leaving local populations even more vulnerable as floodwaters recede.²⁰

Other Factors Contributing to the Spread of Dengue Fever

Many other factors—including rapid urban population growth, increasingly widespread international travel and transport, and disrupted or weakened mosquito control measures—affect where and when dengue outbreaks occur.²¹ Some have called dengue “a disease of poverty” because in areas that lack window screens, municipal drinking water supplies, or trash collection, dengue can run rampant through the population.²² But dengue can also strike the more affluent, especially if they travel internationally. In 2004, a record 27.4 million U.S. travelers visited overseas countries, which was a 12 percent increase from the previous year.²³ International movement of people and cargo can rapidly transport mosquitoes as well as dengue-infected individuals into new, susceptible populations and bring different dengue serotypes together, increasing the risks of DHF transmission. Viruses like dengue are spread internationally by infected travelers who act as disease incubators. As they carry the virus into new regions, outbreaks can result if mosquito vector species that can carry the infection also inhabit the area. Researchers have suggested that infected people rather than infected “stowaway” mosquitoes hiding in airplanes, ship containers, or tires are the most likely source of imported dengue infections.²⁴



Dengue in the Americas

In the 1950s and 1960s, dengue was eliminated from much of Central and South America by mosquito control efforts directed at eradicating yellow fever (which is carried by the same mosquito vector species). But as mosquito

control programs declined in the 1970s, dengue returned because *A. aegypti* reinfested countries from which it had previously been eliminated. A deadly pattern appeared: within a few years of reinfestation, dengue epidemics occur, first with one serotype and then with multiple ones, leading to an increase in DHF.²⁵ In the western hemisphere, the reported number of dengue cases doubled between 1995 and 2001, and the disease continues to spread into new areas with more explosive outbreaks.²⁶ The year 2007 was the worst on record for dengue in over a decade, with more than 900,000 cases of DF and DHF in the western hemisphere.²⁷ With international travel now increasingly widespread, cases of dengue are confirmed every year in the United States, mainly imported by travelers returning from dengue-endemic areas or the southern U.S. border. Many cases go undiagnosed by physicians who don't recognize its symptoms or among those fortunate patients whose symptoms are minor (see text box “Dengue Symptoms to Watch For,” page vi). Yet according to the CDC, “There is a small, but significant, risk for dengue outbreaks in the continental United States.”²⁸



Dengue Fever in the U.S.-Mexico Border Region

Some researchers estimate that 110,000 to 200,000 new infections annually may be transmitted along the U.S.-Mexico border and in the southern United States.²⁹ Along the 2,000-mile U.S.-Mexico border region, the lack of planning to accommodate the tremendous population growth in recent decades has led to inadequate investment in public infrastructure and housing development. As a result, hundreds of thousands of border residents live in communities known as *colonias*. These communities often lack sewer systems, treated drinking water, storm drainage, good-quality housing, or garbage service—all of which can threaten residents' health.³⁰ As global warming brings increasing temperatures and major storm events that augment flooding, disruptions in water and wastewater systems could make these border regions even hotter spots for dengue. While several western hemisphere nations have shown declining dengue incidence rates since the mid-1990s, there have also been some local increases in more recent years. For example, while overall dengue incidence in Mexico has fallen since the mid-1990s, rates reportedly increased by 600 percent between 2001 and 2007. Some researchers think the recent trend there toward higher temperatures and humidity could be allowing dengue mosquito populations to increase and move into new regions.³¹ With millions of crossings back and forth each month among U.S.-Mexico border communities—to visit family and friends, shop, work, and seek the most affordable health care—dengue has and will continue to traverse national boundaries.^{32,33}

This isn't a hypothetical risk: dengue has already infected 40 percent of the population on the U.S. side of some of these border areas. A blood sampling survey in 2004 found evidence of undiagnosed past dengue infection in 40 percent of Brownsville, Texas, residents and in 78 percent of those living in Matamoros in the Mexican state of Tamaulipas. Mosquito larvae were found in 30 percent of homes in both areas.³⁴ With more warming, international travel, and dengue viral strains in circulation, the region is primed for another DHF outbreak. In a large dengue outbreak in 2005 along the Texas-Mexico border, more than 7,000 DF cases and 1,823 cases (26 percent) of DHF were reported in Tamaulipas, along with several cases of locally acquired DHF in Texas, which until recently had not been recorded in the United States.³⁵ A survey of households in Matamoros and Brownsville shortly after the epidemic peaked showed that 32 percent and 4 percent of residents, respectively, had signs of recent dengue—amounting to an additional 6,700 undiagnosed infections in Brownsville.³⁶ There were abundant populations of the two dengue mosquito species in Brownsville; both cities had plentiful used tires and water buckets infested with immature mosquitoes. Less than two-thirds of homes had window and door screens, and less than a quarter of residents reported using insect repellent regularly. All four strains of the dengue virus have circulated in South Texas, raising concerns about increased risk of DHF among those reinfected by different dengue strains.

CHAPTER 2

The NRDC Analysis: Increasing Vulnerability to Dengue in the Americas

The Natural Resources Defense Council (NRDC) mapped data on dengue fever in the Americas from 1995–2007 as well as data on the distribution of the mosquito vectors for the disease in the United States. We chose 1995 as a starting point because it was the first year of the improved disease surveillance program by the Pan American Health Organization (PAHO).³⁷ For a cross-comparison, we also graphed time trends in dengue fever from 1970–2007 using information from WHO’s DengueNet data source and PAHO.³⁸ Data from the United States came from the Centers for Disease Control and Prevention and other sources (see Appendix A, online at www.nrdc.org/health/dengue, for methodology). Our analysis reveals increases over time in the disease in many parts of South and Central America, as well as in the Caribbean and the United States. Rates of dengue hemorrhagic fever (DHF) have also shown an increase during this time frame. Maps of mosquito populations in the United States reveal zones that are vulnerable to possible outbreaks of dengue fever.

The current distribution of dengue shows that five nations in Central and South America (Honduras, Costa Rica, Venezuela, Brazil, and Paraguay) are the most serious hotspots for the disease (Figure 1). With more than 500,000 cases reported in 2007, Brazil has by far the largest number of cases and burden of disease in the western hemisphere (Table 1). Other countries, such as Colombia, Bolivia, the Hispanic Caribbean, Panama, and El Salvador, are also suffering from significant rates of dengue fever. The only country in the western hemisphere with no reported cases of dengue fever in 2007 was Uruguay.

Rates of dengue fever increased by more than 100 percent since 1995 in Bolivia, Costa Rica, El Salvador, parts of the Caribbean, and the United States (Figure 2). There has been an appreciable increase in dengue in recent years in the United States and its neighbors to the south, with annual hemispheric incidence of more than 900,000 cases of dengue fever in 2007 and more than 26,000 DHF cases. Epidemic outbreaks during 2007 in some of the western hemisphere countries affected hundreds of thousands. The United States saw a dramatic increase in the number of

Figure 1: Incidence of Dengue in the Americas, 2007



NOTE: Comparison of dengue incidence rates per 100,000 population in 2007, categorized as low, medium, or high. Data are from the Pan-American Health Organization (PAHO). PAHO data are available online at <http://www.paho.org/english/ad/dpc/cd/dengue.htm>.

Figure 2: Comparison of Dengue Incidence Rates: 2005–2007 Average Versus 1995–1997 Average



NOTE: Comparison of percent changes in dengue plus DHF incidence rates per 100,000 population, average of years 2005–2007 vs. average of years 1995–1997. Data are from PAHO, available online at <http://www.paho.org/english/ad/dpc/cd/dengue.htm>.

PAHO-reported cases by 2007 (488 cases) versus 1995 (7 cases). Other countries, such as Argentina and Chile (Easter Island), which previously did not report any cases of dengue, had the disease by the end of the reporting period. Mexico, Colombia, Nicaragua, and Guatemala reported decreased rates during this time. Note that some of the changes over time and among countries could be due to differences in the resources available for case monitoring and reporting, the relative effect of large outbreaks in 1995, and efforts to control and prevent dengue and DHF since then.³⁹

An assessment of time trends since 1970 shows that there is considerable variability from year to year, but that overall reported cases have substantially increased in the western hemisphere (Figure 3). Reports of dengue hemorrhagic fever also increased significantly since 1995. The total number of cases in the Americas went from 8,228 in 1995 to more than 26,000 in 2007 (see Figure A1 in the online appendix to this paper, available at www.nrdc.org/health/dengue). The rise in DHF may be due in part to increasing international travel and trade, which allows the various serotypes

to circulate more freely and can increase chances of reinfection with different strains. New serotypes were introduced into the Americas in 1995 and 1998, with all four serotypes in circulation by 2007.⁴⁰

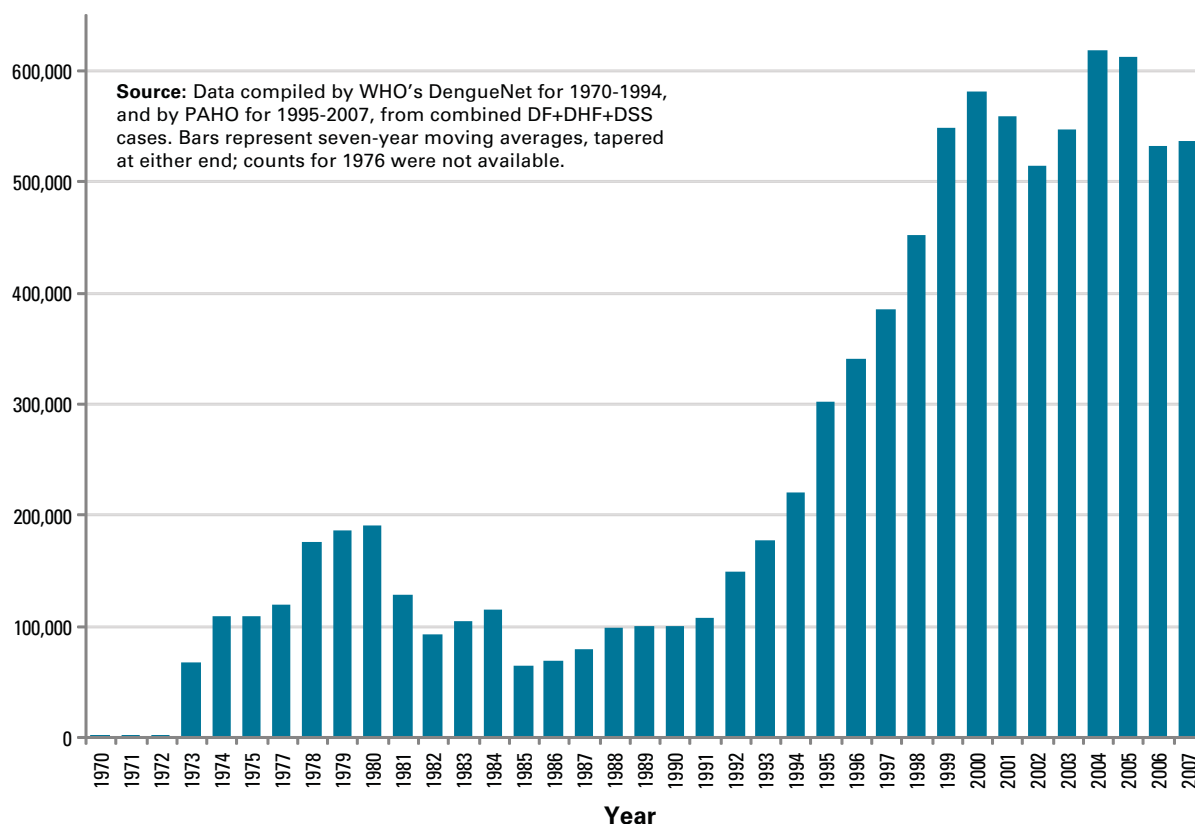
Table 1: Dengue Fever and Dengue Hemorrhagic Fever Cases Reported in 2007

Country	Total Number of Cases
Brazil	559,954
Venezuela	80,646
Mexico	48,436
Colombia	43,227
Honduras	33,508
Paraguay	28,182
Costa Rica	26,440
Hispanic Caribbean	20,668
El Salvador	12,467
Caribbean	10,986
Ecuador	10,587
Bolivia	7,332
Peru	6,907
Guatemala	5,886
Panama	3,402
Nicaragua	1,415
United States	488
Argentina	173
Belize	40
Chile	28
Uruguay	0
Western Hemisphere 2007 Total	900,772

NOTE: Table shows the numbers of combined DF plus DHF case counts reported in 2007 for western hemisphere countries, listed by country from high to low. Data are from the Pan-American Health Organization (PAHO), available online at <http://www.paho.org/english/ad/dpc/cd/dengue.htm>.

Dengue Vulnerability in the United States

There have been imported cases of dengue fever reported in nearly every state of the United States. Nearly 4,000 cases of imported and locally transmitted dengue were reported in the United States from 1995 to 2005. When cases in the Texas-Mexico border region are included, the numbers rise to 10,000. Across the border in Mexico, dengue fever cases during this time numbered in the tens of thousands. In the northern United States, dengue fever is likely to remain a disease of tourists returning from abroad. However, in a swath across the southern and mid-Atlantic states, there is potential for a more serious problem. Our mapping of mosquito prevalence data revealed that the species that can

Figure 3: Rolling Average of Dengue Fever Reported in the Western Hemisphere, 1970–2007

NOTE: Seven-year rolling (or moving) averages of cases of Dengue Fever Reported in the Western Hemisphere, 1970–2007. Data were compiled by WHO's DengueNet for 1970–1994 and by PAHO for 1995–2007.^{41,42} Bars represent the average of values calculated across seven years and also the three preceding and three following years' data when available.

carry dengue are widespread in at least 28 states and the District of Columbia (Figure 4). The map shows the swath of counties reporting the presence of one or both of the two mosquito vector species as of 2005.⁴³ With international travel increasingly common, cases of dengue are confirmed every year in the United States, imported by visitors returning from dengue-endemic areas. During the summer months when adult mosquito vectors are active in the United States, the arrival of infected travelers creates conditions that could be conducive to an outbreak. For example, in some states, such as Oregon, 90 cases of dengue fever have been mapped without either of the vectors present as yet, because travelers infected with the virus brought the disease back with them. Dengue could spread when a critical mass of infected people eventually combines with increased numbers and geographic range of the mosquito vector species here in the United States. An estimated 173.5 million Americans currently live in counties with one or both of the mosquito species, making them vulnerable to spread of the disease.

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U.S. Border States Are Most Vulnerable

The U.S.-Mexico border has been a hotspot for dengue fever with outbreaks in 1995, 1997, and 2005. Substandard housing conditions in communities known as *colonias*, which often lack sewer systems, treated drinking water, storm drainage, good-quality housing, and garbage service, threaten resident's health and increase vulnerability to dengue fever. As global warming increases the frequency and severity of storm events resulting in flooding and disruptions to shelter, water, and wastewater systems, this region's vulnerability to dengue could increase, and the disease could spread northward into the United States. Mexico has a dengue plan that is intended to address some of these concerns in the colonias.



Atlantic and Gulf Coasts Are At Risk

The eastern and Gulf coasts are vulnerable to storms, hurricanes, and flooding that damage homes and critical infrastructure—often creating ideal conditions for increased mosquito populations. In addition, damaged homes, disrupted water and wastewater systems, and displaced populations enhance human-mosquito contact. As global warming amplifies the impact of hurricanes and storms, these coastal areas face increased vulnerability to insect-borne diseases like dengue fever. To help reduce vulnerability and better prepare for the health impacts of global warming, building more storm-resilient housing and strengthening public health infrastructure should become a priority.

(NOTE: Dengue vulnerability in the United States. Among the social and environmental factors that increase community vulnerability to dengue and other infectious diseases are poor municipal infrastructure and frequent storm damage to homes. Red areas of the map show U.S. counties that have reported the presence of one or both of the mosquito species (*Aedes aegypti* and *Aedes albopictus*) that can potentially transmit dengue fever; blue regions highlight the area encompassing most of the positive counties. Numbers of suspected cases of dengue infection reported from 1995–2005, inclusive, are shown below each state name.⁴⁴ Reported counts of suspected dengue fever cases are also included for the six Mexican states that border the United States.⁴⁵

CHAPTER 3

Recommendations to Help Limit the Spread of Dengue Fever

The effects of climatic change in the United States could create conditions that enhance the spread of dengue. Clinicians, local health officials, and the public need to be aware of the dangers of this disease. Many factors contribute to the disease transmission cycle, and a number of steps can be taken to help limit its spread:

1) Improve environmental monitoring

Active mosquito trapping can help detect and track the occurrence and spread of vector species, habitat areas, and the presence of the dengue virus in mosquitoes. Ongoing research is also needed because global warming's effects on temperature and rainfall patterns may affect the risks of dengue outbreaks differently in different areas.⁴⁶

Systems are being developed that can combine environmental monitoring data on mosquito breeding areas with information on local dengue infections into web-based, user-friendly features that give a visual sense of what mosquito breeding “hotspots” look like and what factors can contribute to the expansion of mosquito habitat.⁴⁷ A new arsenal of geographic information systems (GIS) and remote sensing tools have already been used to map case locations and relationships between environmental and demographic changes and dengue risk factors in Argentina, Brazil, Mexico, and several Asian countries.⁴⁸

2) Support better health surveillance

Dengue should be made a nationally notifiable disease. A proactive surveillance system should be established for collection and timely virologic testing and analysis of blood samples from suspected dengue cases. In the United States, the public health system largely depends upon clinicians and state health departments to recognize and report suspected cases.⁴⁹ This in turn depends on patients, visiting health care providers who can recognize and report suspected cases and send blood samples for testing. As a result, the number of cases reported is probably an underestimate of the actual number of cases. Surveillance results suggest that local transmission should be publicized as an early warning system alerting the public to take protective action and practitioners to be vigilant in timely diagnosis and treatment. In particular, “sentinel surveillance” of returning travelers could provide a forewarning of imported cases.⁵⁰ Consistent, centrally reported and confirmed dengue case surveillance data—with enhanced international coordination, data sharing, lab capacity, and outbreak notification among nations that share border communities, like the United States and Mexico—is needed in order to better understand the changing incidence of the disease and to evaluate control programs. The Border Infectious Disease Surveillance (BIDS) Project, a binational collaboration begun in 1997, “was designed to bridge this surveillance gap” and has successfully enhanced local disease reporting for a number of infections, including dengue.⁵¹

Better education of clinicians and health departments is essential to help recognize dengue infections and treat them immediately. Some clinicians may not be aware that dengue should be considered in a detailed, systematic method of diagnosis for patients with fever and a history of recent travel to dengue-endemic areas.⁵² To diagnose dengue, doctors need to obtain two blood samples from suspected cases one to two weeks apart.⁵³ Proper treatment and case management can save lives and reduce DHF death rates from an estimated 20 percent among those untreated to less than 1 percent for those with appropriate care.⁵⁴

3) Improve mosquito control

Improving vector control is the primary means of controlling the spread of dengue. Pesticide sprays to kill adult mosquitoes are usually ineffective.⁵⁵ Spraying is also too costly to be a useful long-term solution and can result in insecticide-resistant mosquitoes.⁵⁶ Furthermore, because *A. aegypti* spends much of its adult life inside homes, spraying pesticides outdoors is unlikely to be helpful. The most effective way to control mosquitoes is to eliminate, drain, clean, or treat the containers, trash, or tires that can hold standing water and act as habitat where immature mosquitoes develop.⁵⁷ Waste tires are hazardous because they serve as mosquito breeding grounds, yet millions of them accumulate in the Texas-Mexico border region. More international collaboration is needed to establish trade markets for waste tires to help reduce disease risk.

Where there is emphasis on health education and mobilization of communities to identify and eliminate local vector breeding sites, dengue control programs are more likely to meet with long-term success. After storms, floods, and hurricanes, federal assistance for emergency vector surveillance and control should be made available immediately to affected localities.

4) Create climate- and disease-resilient homes and communities

Dependable piped water systems and trash collection as well as access to safe drinking water will reduce mosquito breeding habitat and help protect residents of poor communities that are most at risk. Installing window and door screens can reduce contact with mosquitoes, and timely emergency response after hurricanes and similar events can also help minimize human-mosquito contact. Provision of regular health care will strengthen the underlying wellness and knowledge base for communities at risk for dengue, which today (with frequent air travelers everywhere) may include any area where dengue mosquitoes reside.

5) Reduce global warming pollution to decrease the extent and severity of warming

Because climate change may expand the geographic range of dengue's vectors, addressing global warming at its source could help limit dengue and other climate-health risks, which include heat wave deaths, increases in air pollution-related illnesses, and increasingly frequent intense storms with flooding. In that regard, governments should enact mandatory legislation to reduce global warming pollution and combat climate change. In addition, governments must act to protect communities from the impacts of climate change already underway.

6) Provide information for travelers visiting high-risk dengue areas

The CDC has estimated that as many as 1 in 1,000 travelers to dengue-endemic countries becomes ill. Travelers can reduce their risks by sleeping in well-screened or air-conditioned hotels that strive to keep their facilities free of waste containers that can hold shallow standing water and harbor immature mosquitoes. In areas with dengue fever, use of insecticide-treated curtains is a useful way of reducing transmission.⁵⁸ Travelers should also limit outdoor activities at dusk and dawn when mosquitoes are most active, apply an insect repellent with 20–30 percent DEET on exposed skin in the morning and late afternoon (over sunscreen), and consider wearing long-sleeved shirts and long pants. Adults should apply repellent to children, avoiding their eyes, mouth, and hands. Products that combine repellents and sunscreen are generally not recommended because sunscreens need to be reapplied more frequently. Adults can protect infants by using a carrier draped with mosquito netting that has an elastic edge for a tight fit. If you suspect you have a dengue infection while traveling—the “dengue triad” of symptoms include high fever; rash; and severe headache with bone, joint, and muscle pain—see a doctor. In the meantime, avoid aspirin and ibuprofen because they can increase bleeding; instead opt for acetaminophen to reduce fever and pain.⁵⁹ Before you travel, find out what parts of the world are currently experiencing dengue outbreaks by visiting the CDC's *Dengue Outbreak Notice* website or *Traveler's Health-Yellow Book* on dengue.^{60,61}

Dengue fever and dengue hemorrhagic fever are both regional and global health crises that demand coordinated government action to minimize risks. There are active, ongoing research efforts to develop an effective dengue vaccine, which would be a key weapon in “the dengue war.”⁶² The complete arsenal in combating dengue will need to include strategies to reduce vector populations; educate clinicians, travelers, and the public; improve urban housing and sanitation; and limit global warming, which contributes to the spread of this dreaded disease and increasingly brings global issues much closer to home.

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