A National Public Health Framework for the Prevention and Control of Vector-Borne Diseases in Humans

Centers for Disease Control and Prevention
National Center for Emerging and Zoonotic Infectious Diseases

Amblyomma maculatum

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Cover

Clockwise from top right:

- Blacklegged tick (*Ixodes scapularis*), James Gathany photographer
- *Aedes aegypti* mosquito, James Gathany photographer
- Illustration of the United States
- Oriental rat flea (*Xenopsylla cheopsis*), James Gathany photographer

Accessible Version: www.cdc.gov/ncezid/dvbd/framework.html

Introduction and Scope

Our nation's ability to defend against the present and future threat of vector-borne diseases relies on a comprehensive national system that is able to detect, prevent, and respond to these threats. A concerted and sustained effort is needed to address significant challenges and reverse the upward trends in illness, suffering, and death from vector-borne diseases. This effort must enhance collaboration, coordination, and communication across human, animal, and environmental health sectors, as well as other relevant sectors, to address vector-borne threats at the human-animal-environment interface (a One Health approach).

To reverse the current upward trends in vector-borne diseases and to increase the nation's ability to protect the U.S. population from these diseases, five federal departments and the Environmental Protection Agency contributed to developing a national framework for vector-borne disease prevention and control. These federal partners represent the primary federal departments and agencies engaged in vector-borne disease prevention and control (see Participant List).

A National Public Health Framework for the Prevention and Control of Vector-Borne Diseases in Humans is consistent with the National Biodefense Strategy's objective 2.1[1], to promote measures to prevent or reduce the spread of naturally occurring infectious diseases (Sub-objective 2.1.3: strengthen multidisciplinary efforts to control vector-borne disease domestically and internationally).

The scope of this framework includes federal activities necessary to detect, prevent, and control vector-borne diseases in humans in the United States. While this framework is domestically focused and limited to activities within the mission of the federal government, it relates to a broader range of critical activities such as clinical care, vector control services, and international work. Successful implementation of the framework will require collaboration within and outside of the federal government.

Aedes aegypti

BOX 1. VECTOR-BORNE INFECTIONS AND DISEASES REPORTED BY STATES TO CDC

- Anaplasmosis/Ehrlichiosis infections
- Babesiosis
- California serogroup viruses
- Chikungunya virus
- Dengue viruses
- Eastern equine encephalitis virus
- Lyme disease
- Malaria
- Plague
- Powassan virus
- Spotted fever rickettsiosis
- St. Louis encephalitis virus
- Tularemia
- Western equine encephalitis virus
- West Nile virus
- Yellow fever virus
- Zika virus

BOX 2. VECTOR-BORNE DISEASE PATHOGENS NEWLY DISCOVERED OR FIRST REPORTED IN THE UNITED STATES SINCE 2004

- *Rickettsia parkeri* (tick)
- Bourbon virus (likely tick)
- *Rickettsia* species 364D (tick)
- *Ehrlichia muris eauclairensis* (tick)
- Heartland virus (tick)
- *Borrelia miyamotoi* (tick)
- *Borrelia mayonii* (tick)
- Chikungunya virus (mosquito)
- Zika virus (mosquito)

The Problem

Everyone in the United States is at risk from endemic and emerging diseases transmitted by ticks, mosquitoes, fleas, and other blood-feeding vectors. Certain demographic groups are at even greater risk of contracting or suffering adverse consequences from specific vector-borne diseases. Vector-borne diseases, such as West Nile virus, plague, Lyme disease, and Rocky Mountain spotted fever, can cause serious illness or even death. During the last 15 years, the number of vector-borne disease cases has increased dramatically as the ranges of vectors have expanded and the number of emerging pathogens have multiplied[2]. A recent CDC prioritization workshop identified the top eight priority zoonotic diseases of national concern for the United States. Three, including West Nile virus, plague, and Lyme disease, are vector-borne diseases[3].

More cases. States report more than 17 vector-borne diseases to CDC (see Box 1). In the United States and its territories, the annual number of vector-borne disease cases in people reported to CDC **doubled** from 27,388 cases in 2004 to 53,591 cases in 2018[2]. In 2018, state and local health departments reported 47,743 cases of tickborne disease to CDC. This is the highest number of tickborne diseases ever reported to CDC[4].

Tickborne diseases: Nationally reported tickborne disease cases more than doubled from 2004 to 2018 and are now at an all-time high[2]. Lyme disease accounted for more than 7 out of 10 of all reported tickborne disease cases in 2017[4].

As high as they are, reported cases significantly under-represent all vector-borne disease cases. Reported cases of Lyme disease[5] and West Nile[6] virus represent less than 1 in 10 of all estimated cases.

Mosquito-borne diseases: West Nile virus disease occurs annually and is well-established in the United States. In addition, the nation is increasingly threatened by invasive, epidemic-prone viruses such as dengue (2011-2012, 2015), chikungunya (2013), and Zika (2016).

More pathogens. More than 100 vector-borne viral, bacterial, and parasitic pathogens are known to cause disease in people. Since 2004, nine vector-borne viruses and bacteria new to the United States have been identified (see Box 2). Some of these pathogens are invasive species (see Box 3), but others have been recently discovered in the United States. The extent of their ranges, the populations at risk, and the amount of disease and disability they cause are still not fully understood. What is certain is that more pathogens put more Americans at risk.

More people at risk. The geographic habitat range of ticks[7], mosquitoes[8], and fleas[9], that can transmit pathogens and cause disease has expanded within the United States. The expansion of *Aedes aegypti* mosquitoes and *Ixodes scapularis* ticks are of particular concern. Furthermore, in 2017 an invasive vector, *Haemaphysalis longicornis* (the Asian longhorned tick) was identified for the first time in the United States. This exotic tick causes severe illness or death in people in other parts of the world, although there is no evidence of pathogen transmission to date in the United States[10]. As of 2020, 14 states have reported infestations[11]. *H. longicornis* ticks have been detected on at least 16 different hosts, including wildlife, livestock, pets, and people.

BOX 3. INVASIVE SPECIES

Invasive species are harmful plants, animals, vectors, or pathogens newly introduced into an area, which bring with them negative impacts. Invasive species can introduce new pathogens or transmit existing pathogens in an area. Increased global trade, commerce, and travel increases the likelihood of new invasive species being introduced to the United States and other countries.

Challenges in the Prevention and Control of Vector-Borne Diseases

Our nation's ability to detect and respond to vector-borne disease threats can be improved by addressing the following significant challenges.

Ability to diagnose vector-borne diseases varies. Rapid, accurate diagnosis is critical to the timely, effective response to vector-borne disease outbreaks. Diagnosis of vector-borne diseases requires the patient to seek care and clinicians to be familiar with vector-borne diseases and order U.S. Food and Drug Administration (FDA)-cleared laboratory tests.

Stressed surveillance systems. It is critical to know where disease cases occur and when they increase. Decreased financial support has eroded the ability of state and local public health officials to accurately monitor human disease incidence and to monitor changes in vector populations that can predict increased risk, resulting in significant underreporting[12]. The number of Lyme disease cases, for example, now estimated at more than 300,000 annually, have overburdened the ability of some health departments to investigate and report suspected cases, leading to considerable underreporting and underestimation of the disease burden[13,14].

No vaccines. In 2019, a dengue vaccine was approved by the FDA in the United States for use in children 9–16 years old living in an area where dengue is common (the U.S. territories), with laboratory confirmed prior dengue virus infection. It is not available at this time. No other licensed vaccines for humans are currently available for other vector-borne disease pathogens present in the United States. As a result, prevention strategies rely on use of vector control and personal protection (e.g., insect repellents, protective clothing) to prevent infection and disease.

Few vector-borne disease prevention and control measures. Prevention of vector-borne disease often requires vector control. No proven tick control methods exist to prevent disease. Integrated pest management can be effective for the control of some mosquito vectors, like the primary mosquito vector of West Nile virus[15]; however, these chemical control measures may be considered unacceptable or cost-prohibitive to communities. When used consistently and correctly, personal protective measures, such as insect repellents, are effective for preventing mosquito, tick, and flea bites; however, most people do not take these precautions[16]. Therefore, vector control options that are cost-effective and socially, culturally, and environmentally acceptable are needed.

Limited capacity to respond. The vast majority of vector control organizations in the United States are locally controlled and funded, and states manage vector control activities differently[17]. Many communities, including some at significant disease risk, are without any vector control programs. In a recent national survey of over 1,000 mosquito control organizations, more than 80% reported needing improvement in core capacities, such as conducting mosquito surveillance and testing for pesticide-resistance[18]. Communication and coordination among vector control operations and between them and public health officials is often lacking[19]. Further, prevention and control activities for emerging versus endemic vector-borne diseases may differ. Therefore, a set of diverse community level prevention and control activities are needed.

Lack of interconnected, quality data. Clinical, surveillance, environmental, animal and wildlife, and meteorological data relevant to the control of vector-borne diseases exist in a variety of non-standardized sources and formats across the public and private sectors that cannot easily be linked or shared. Developing systems that allow private and public sectors to responsibly collect, use, and share standardized data sets can help address vector-borne disease threats and advance solutions with emerging technologies (e.g., artificial intelligence).

Innovation outpaces regulatory processes. New tools and products do not always fit into existing regulatory structures, and innovation is often ahead of regulatory processes. This can result in delays and increased costs in bringing urgently needed novel diagnostic, prevention, and control products to the field. Flexibility in regulatory processes is needed.

Limited options for treatment. New treatment options are needed to treat vector-borne diseases. No medicines are available to treat viral vector-borne diseases, but symptoms can be clinically managed. For bacterial, rickettsial, and parasitic diseases for which treatments do exist, people may still suffer ongoing symptoms, severe disease, and death. New treatment options may help reduce disease impacts. Federal open innovation activities, such as the U.S. Department of Health and Human Services (DHHS) *Lyme Innovation Initiative,* may help identify challenges and solutions through public-private partnerships[20].

More detailed discussions of these and other challenges in the domestic prevention and control of vector-borne diseases can be found in Petersen et al. (2019)[21] and Beard et al. (2019)[22].

Solution

VISION

A NATION WHERE VECTOR-BORNE DISEASES NO LONGER THREATEN HUMAN HEALTH AND WELL-BEING

MISSION

PROTECT PEOPLE FROM ILLNESS, SUFFERING, AND DEATH DUE TO VECTOR-BORNE DISEASES

GOALS

1. Better understand when, where, and how people are exposed to and get sick or die from vector-borne diseases
2. Develop, evaluate, and improve tools and guidance for the diagnosis and detection of vector-borne diseases
3. Develop, evaluate, and improve tools and guidance for the prevention and control of vector-borne diseases
4. Develop and assess drugs and treatment strategies for vector-borne diseases
5. Disseminate and support the implementation of effective public health and vector control products, tools, and programs to prevent, detect, diagnose, and respond to vector-borne disease threats

GOAL 1: Understand

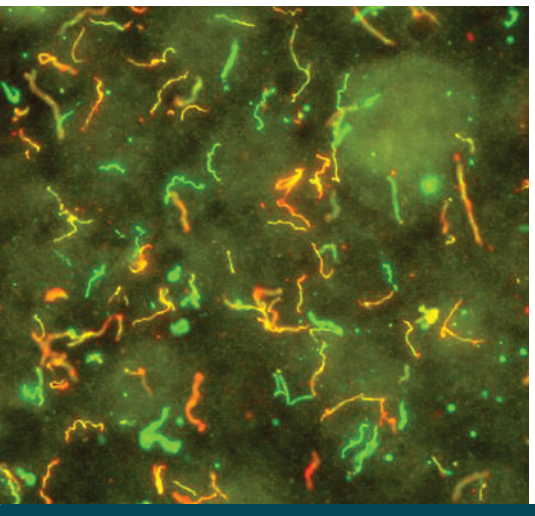
Better understand when, where, and how people are exposed to and get sick or die from vector-borne diseases

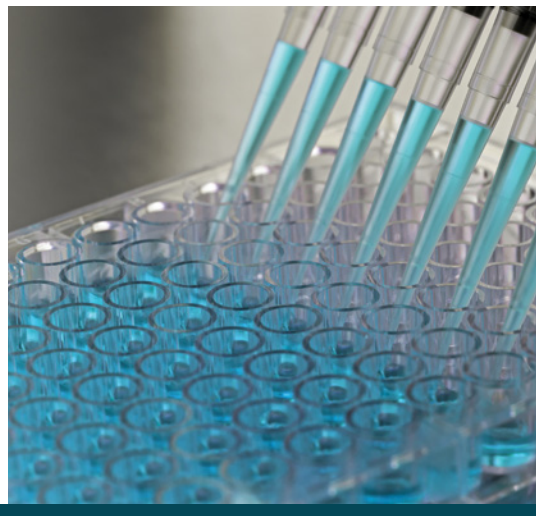
STRATEGIC PRIORITY	FEDERAL DEPARTMENT WITH ACCOUNTABILITY
1. Conduct research to better understand vectors and vector-borne pathogens, including how they are maintained in the environment, transmitted, and cause illness	DHHS (IOS/OS, CDC, FDA, NIH) DOD DOI (NPS, USGS) USDA
2. Identify risk factors for exposure to vector-borne pathogens and develop risk predictions and decision support tools	DHHS (IOS/OS, CDC, NIH) DOD DOI (NPS, USGS) USDA
3. Maintain and improve surveillance systems for disease vectors, animal hosts, and vector-borne diseases	DHHS (IOS/OS, CDC) DOD DOI (NPS, USGS) USDA
4. Understand the effects of vector-borne diseases on humans, including immune responses, persistence, recurrence, and outcomes	DHHS (IOS/OS, CDC, FDA, NIH) DOD

GOAL 2: Detect and Diagnose

Develop, evaluate, and improve tools and guidance for the diagnosis and detection of vector-borne diseases

STRATEGIC PRIORITY	FEDERAL DEPARTMENT WITH ACCOUNTABILITY
1. Identify and characterize novel vector-borne disease pathogens and their clinical manifestations	DHHS (IOS/OS, BARDA[23], CDC, FDA, NIH) DHS DOD DOI (USGS) USDA
2. Develop, evaluate, and improve diagnostic tests for vector-borne disease pathogens	DHHS (IOS/OS, BARDA, CDC, FDA, NIH) DOD DOI (USGS) USDA
3. Develop and evaluate evidence-based recommendations and guidelines on vector-borne disease diagnosis	DHHS (IOS/OS, CDC) DOD
4. Develop, maintain, and distribute diagnostic resources[24] to facilitate research, development, and testing capacity	DHHS (IOS/OS, CDC, NIH) DOD USDA

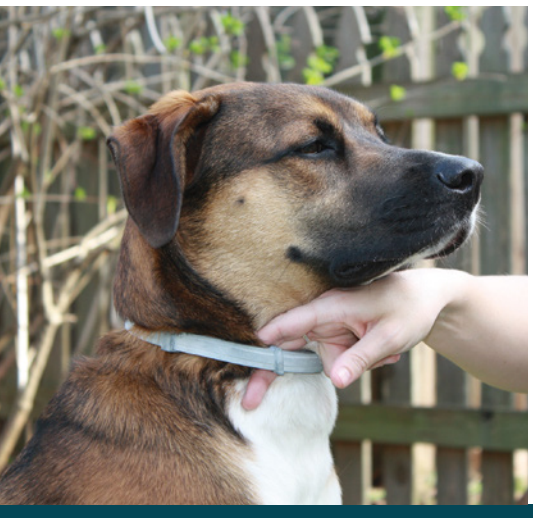


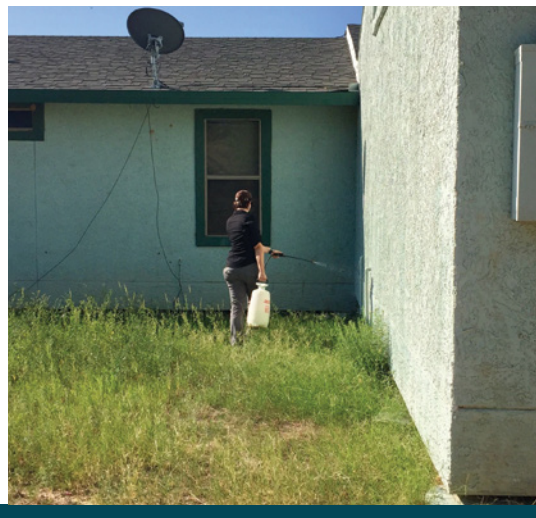


GOAL 3: Prevent and Control

Develop, evaluate, and improve tools and guidance for the prevention and control of vector-borne diseases

STRATEGIC PRIORITY	FEDERAL DEPARTMENT WITH ACCOUNTABILITY
1. Develop, evaluate, and improve safe and effective vector-borne disease prevention tools such as vaccines and vector control strategies[25]	DHHS (IOS/OS, BARDA, CDC, FDA, NIH) DOD DOI (USGS) EPA USDA
2. Develop and evaluate evidence-based recommendations and guidelines on vector-borne disease prevention	DHHS (IOS/OS, CDC) DOD DOI (USGS) USDA
3. Develop and evaluate tools and processes for responding to public health emergencies	DHHS (IOS/OS, CDC, FDA, NIH) DOD EPA USDA

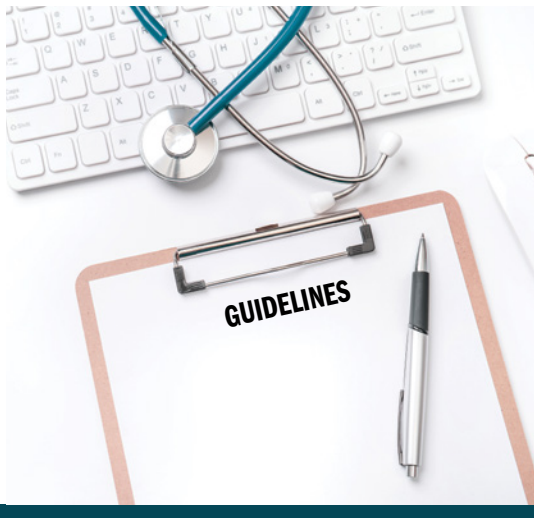




GOAL 4: Treat

Develop and assess drugs and treatment strategies for vector-borne diseases

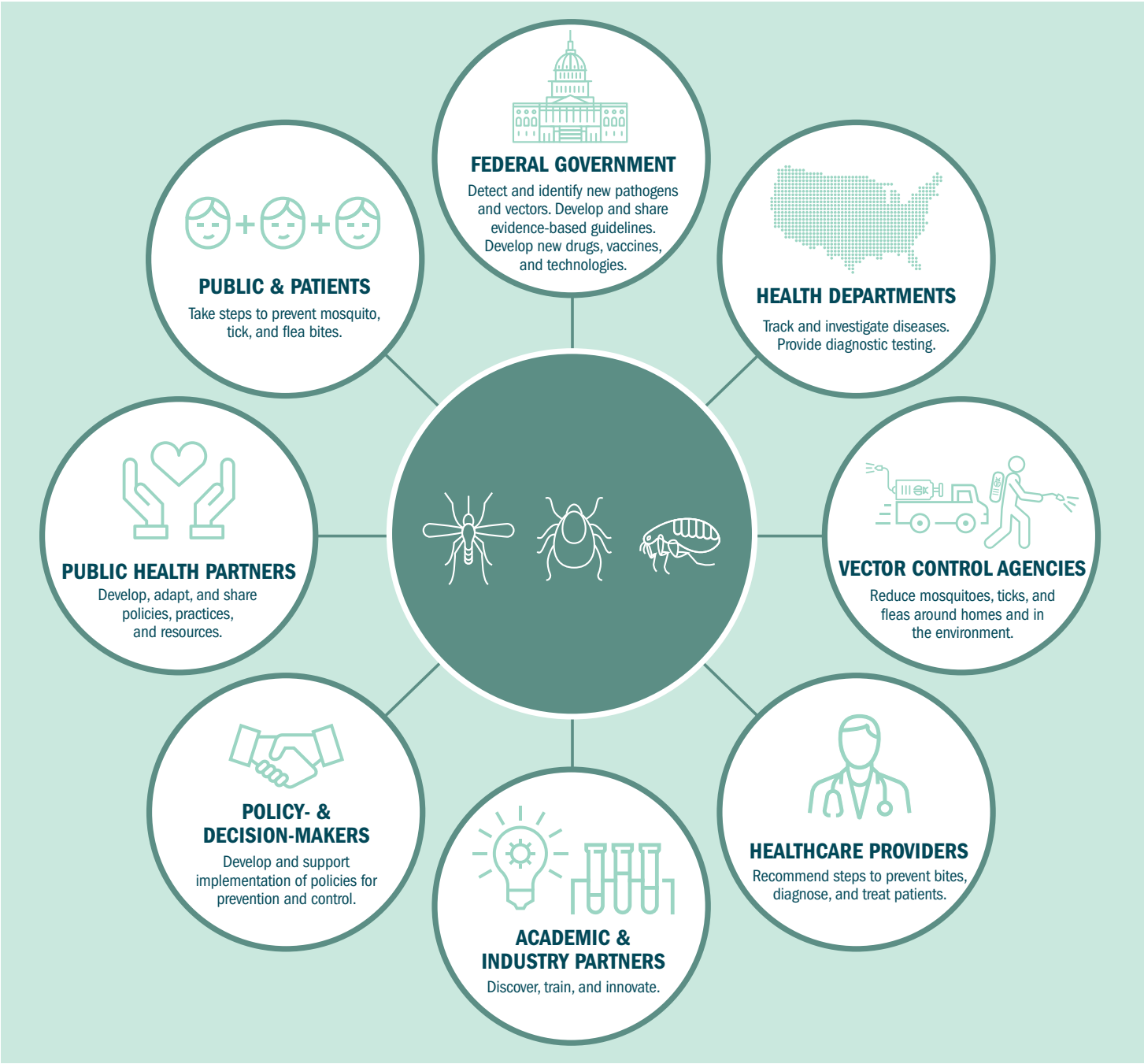
STRATEGIC PRIORITY	FEDERAL ENTITY WITH ACCOUNTABILITY
1. Identify, develop, and evaluate safe and effective drugs and treatment strategies for vector-borne diseases	DHHS (IOS/OS, BARDA, FDA, NIH) DOD DOI (USGS) USDA
2. Develop evidence-based recommendations and guidelines on the treatment and management of vector-borne diseases	DHHS (IOS/OS, CDC) DOD DOI (USGS) USDA
3. Evaluate drug and treatment use patterns to inform treatment guidelines and recommendations	DHHS (IOS/OS, CDC, FDA) DOD DOI (USGS)



GOAL 5: Disseminate, Support, and Respond

Disseminate and support the implementation of effective public health vector control products, tools, and programs to prevent, detect, diagnose, and respond to vector-borne disease threats

STRATEGIC PRIORITY	FEDERAL ENTITY WITH ACCOUNTABILITY
1. Disseminate evidence-based information about vector-borne disease prevention and control, guidelines, and recommendations to public health partners and the public	DHHS (IOS/OS, CDC, FDA) DOD DOI (NPS) EPA USDA
2. Ensure current and future capacity to implement safe, effective, and publicly accepted vector-borne disease diagnostics, surveillance, control, and prevention programs[26]	DHHS (IOS/OS, BARDA, CDC, FDA, NIH, IOS/CTO) DOD USDA
3. Implement, monitor, evaluate, and further adapt public health programs and tools	DHHS (IOS/OS, CDC, FDA) DOD DOI (NPS) USDA
4. Respond to public health emergencies resulting from vector-borne disease threats	DHHS (IOS/OS, ASPR, BARDA, CDC, FDA, NIH, IOS/OCTO) DHS (FEMA) DOD DOI (NPS) EPA USDA
5. Clarify, facilitate, and improve processes to bring regulated diagnostic tests, treatment strategies, vaccines, and vector control products and procedures to market	DHHS (IOS/OS, BARDA, FDA, NIH, IOS/CTO) DOD EPA USDA



Network Map

This document details the strategic priorities of the federal government that will lay a framework for critical vector-borne disease prevention and control activities. However, the federal government cannot address the complex challenges presented by vector-borne diseases alone.

To successfully prevent and control vector-borne diseases in humans, a multidisciplinary set of stakeholders must be engaged, activated, and resourced. The stakeholders include the federal government; state, tribal, local, and territorial health departments; vector control agencies; healthcare providers; academic and industry partners; policy and decision-makers, including Congress and elected community leaders; public health partners, such as nonprofit organizations and associations of medical, entomological, and vector control professionals; and the public, including patients.

Looking Forward

The *National Public Health Framework for the Prevention and Control of Vector-Borne Diseases in Humans* lays a foundation for the development and execution of a full National Strategy that details the activities needed to accomplish the articulated goals. This National Strategy was authorized by the Kay Hagan TICK Act of 2019 with oversight and coordination delegated to the Office of the Secretary in DHHS. The National Strategy shall include objectives, activities, performance metrics, as well as a coordination and monitoring plan. The plan will address the challenges outlined above and will be prepared by the federal entities accountable for the work, in consultation with stakeholders. To protect the nation and save lives, success depends on continued collaboration, support, leadership, and excellence in innovation and program implementation.

Participating Federal Departments

DEPARTMENT OF HEALTH AND HUMAN SERVICES (DHHS)

- Centers for Disease Control and Prevention (CDC)
  - *National Center for Emerging and Zoonotic Infectious Diseases (NCEZID)*
  - *National Center for Environmental Health and Agency for Toxic Substances and Disease Registry (NCEH and ATSDR)*
- Immediate Office of the Secretary; Office of the Secretary (IOS/OS) and Office of the Chief Technology Officer (IOS/CTO)
- Office of the Assistant Secretary for Preparedness and Response (ASPR), Biomedical Advanced Research and Development Authority (BARDA)
- Food and Drug Administration (FDA)
  - *Office of the Chief Scientist, Office of the Commissioner*
- National Institutes of Health (NIH)
  - *National Institute of Allergy and Infectious Diseases (NIAID)*

DEPARTMENT OF DEFENSE (DOD)

- Armed Forces Pest Management Board (AFPMB)
- Defense Health Agency, Assistant Director for Combat Support, Public Health Division, Armed Forces Health Surveillance Branch (AFHSB), Global Emerging Infections Surveillance (GEIS)

DEPARTMENT OF AGRICULTURE (USDA)

- Agricultural Research Service (ARS)
- Animal and Plant Health Inspection Service (APHIS)

ENVIRONMENTAL PROTECTION AGENCY (EPA)

- Office of Pesticide Programs (Office of Chemical Safety and Pollution Prevention)

DEPARTMENT OF THE INTERIOR (DOI)

- National Park Service (NPS)
- U.S. Geological Survey (USGS)

OTHER INTERDEPARTMENTAL PARTICIPANTS

- National Invasive Species Council (NISC) Secretariat

Consulting Federal Department

DEPARTMENT OF HOMELAND SECURITY (DHS)

- Federal Emergency Management Agency (FEMA)

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21. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6367643/
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23. BARDA works on vector-borne diseases that have been identified by the Department of Homeland Security as a national security threat.
24. For example: maintaining pathogen reference collections and distributing validation panels and reagents.
25. For example: insect repellents, pesticides, wildlife and habitat management, and seasonal forecasting.
26. For example: staffing, training, and workforce development; providing equipment, supplies, and other resources; providing reagents, tests, and technical assistance.