

Climate Change:

Vector-Borne Diseases and Their Control; Mosquitoes and Ticks

William H. Meredith, PhD¹ and Stephen C. Eppes, MD²

1. Environmental Program Administrator Delaware Mosquito Control Section, DE Division of Fish and Wildlife, DE Dept. of Natural Resources and Environmental Control

2. Vice Chair of Pediatrics Associate Infection Prevention Officer, Professor of Pediatrics, Sidney Kimmel Medical College at Thomas Jefferson University

Whoever would study medicine aright must learn of the following subjects. First he must consider the effect of the seasons of the year and the differences between them. Secondly he must study the warm and the cold winds, both those which are in common to every country and those peculiar to a particular locality. Lastly, the effect of water on the health must not be forgotten. – Hippocrates

Introduction

Human infectious diseases are sensitive to weather and climate in a variety of ways: impact on vector-borne disease transmission, pathogen survival outside the host, environmental contamination, food and water-borne infection, and disruptions of public health systems by disasters such as hurricanes and floods. One needs only consider the recent disasters on the United States mainland and in Puerto Rico as examples. In the continental United States during modern times, the most common mosquito-transmitted diseases are West Nile virus and several other encephalitis viruses. In southernmost areas of Florida and Texas, dengue and Zika viruses are found sporadically, usually resulting from travel to out-of-country endemic areas, although local transmissions can also occur. In the U.S. the most common diseases transmitted by ticks are Lyme disease, Rocky Mountain Spotted Fever, anaplasmosis and ehrlichiosis.

Vector-borne diseases affecting humans can vary in frequency and intensity depending upon population abundances of the vectors transmitting disease pathogens. In turn, vector population abundances can be influenced by environmental and ecological factors such as temperature, precipitation, humidity, photoperiod, food availability, habitat type, predation, inter-species competition and other parameters. Among these factors, climate change and particularly warming temperature regimes can cause some vector populations to become more abundant in given regions or areas, or to be more prevalent longer throughout the year, and in happening can lead to more disease problems for humans. This paper examines such phenomena for mosquitoes and ticks, which are major arthropod vectors for several kinds of diseases affecting people.

Mosquitoes

Warmer, longer, possibly wetter mosquito-production seasons can be an effect of warming climates. The present mosquito season in Delaware typically starts around mid-March and ends around mid-November, making for about an 8-month production period, having about a 5-1/2 month core or peak period from early May into mid-October. But what might happen if Delaware's climate warms over the next several decades and perhaps becomes more like what's

experienced in South Carolina, Georgia or even northern Florida, which is a possibility that some climate change models indicate could happen? Under such conditions, the mosquito- production season might then start in mid-February and end around mid-December, making for a 10-month season, with a 7-1/2 month core or peak period from early April into mid-November. The need to control mosquitoes in Delaware would then last about 2 months longer than at present, being about 25% longer.

Indications of larger mosquito populations that might result from warming climates could turn-up in the 4 types of operational indicators that most all modern mosquito control programs use:

- Higher larval dipper counts
- Higher adult light trap counts
- Higher landing/biting rate counts
- More public complaints and requests for mosquito relief

Operational indicators of mosquito-borne arbovirus presence that might increase with warming climates include:

- Presence of viral antibodies in sentinel chicken blood samples
- Presence of virus in wild bird brain tissues
- Presence of virus in mosquito collections (“mosquito pools”)
- And unfortunately, human and equine arbovirus cases

Mosquitoes are notorious for transmitting many types of diseases adversely affecting humans. In Delaware, we’re primarily concerned with West Nile virus (WNV) and eastern equine encephalitis (EEE), with both arboviruses endemic in wild bird populations, and can be transmitted from birds to humans by certain types of mosquito species that serve as “bridge” vectors. There are also some lesser concerns in Delaware for dengue fever and now more recently for chikungunya and Zika too, which can all be brought into Delaware as imported cases by people who’ve become infected elsewhere in tropical or sub-tropical regions. This could then cause some of our local mosquitoes (e.g. the Asian tiger mosquito, *Aedes albopictus*) to contract these pathogens when they bite an infected traveler who’s now in Delaware, and in turn via these infected mosquitoes biting other people could cause local disease transmissions or even set-off a larger outbreak.

Historically up until the early 1900s and the advent of modern medicine, appearance of organized mosquito control, and improved habitation and sanitary conditions, malaria was endemic in Delaware, and native mosquito vectors for this disease are still quite abundant in our state. Up until the mid- to late 1880s, yellow fever occasionally occurred in Delaware and other eastern seaboard locations during late summer, primarily associated with sailing ship commerce in coastal seaports. Problems caused by these two diseases were most evident during the warmest time of year.

Warmer temperatures as found with warming climates can exacerbate the potential for mosquito-borne disease transmissions in several ways besides just having more mosquitoes around for longer periods of time. Higher pathogen amplification can occur within individual mosquitoes, making for higher viremia levels and thereby increase their infectious nature. Faster pathogen replication rates can also occur in mosquitoes, perhaps reducing the cycle time for when a

mosquito first picks- up a pathogen to when it's then capable of transmitting it to people from what was maybe 5-6 days to then become only 3-4 days. The more pathogen-infected mosquitoes there might be around (whether in terms of absolute numbers or percentages) that might then also have higher viremia levels, then the greater the potential for disease transmissions to humans.

A major concern that we have in Delaware for impacts of warming climate on mosquito-borne diseases is northward expansion of geographic ranges for mosquito species that can be very competent vectors for disease transmission. First and foremost for this concern is with the yellow fever mosquito, *Aedes aegypti*, which is the primary vector not only for its namesake yellow fever, but is also a primary vector in tropical, sub- tropical, and even more southerly temperate areas for dengue fever, chikungunya and Zika. It's a peri-domestic species that does very well in high-density human population locations, essentially having evolved to be with and around people. At present along the eastern seaboard, *Ae. aegypti* is common only as far north as about central South Carolina, but can infrequently be found in quite low numbers as far north as southwestern Connecticut. This species in recent times in Delaware has been found in a single adult light trap collection in the Seaford area in 2012, and similarly in a single adult light trap collection in the Milford area in 2015. We are now carefully monitoring to see if this very troublesome species might become more abundant in our state with time, as our climate continues to slowly warm. If such happens, then the potential for transmission of these arboviral diseases will increase. It should be noted that in recent years *Aedes aegypti* has been found year-around in the Washington, D.C. area (at about the same latitude as southern Delaware), where it now successfully overwinters in the capital's subway system.

The Asian tiger mosquito (*Aedes albopictus*) is a non- native, invasive species that first came into the United States in the Houston area in 1985 via imported used tires from Japan, and has since become the #1 pest mosquito problem in urban and suburban locations throughout Delaware, as well as other locations as far north as northern New Jersey and New York City. It's also a secondary vector in Delaware for West Nile virus (the primary vector for WNV in Delaware is the common house mosquito, *Culex pipiens*), and is a known vector in warmer climates for dengue fever, chikungunya and Zika. There is now concern that with warming climate this species will spread farther north into upstate New York and New England, bringing both its pestiferous nature and disease transmitting potential with it.

Aedes aegypti (the yellow fever mosquito) is a superb vector for mosquito-borne diseases, in that it feeds almost exclusively on people; the female in order to meet its ovipositioning-driven protein needs will take quick blood meals, flitting about from person-to-person potentially biting several people during a single feeding period; it can be very common in backyards; and will readily enter houses to feed on sleeping people within and to rest. *Aedes albopictus* (the Asian tiger mosquito) is not quite as competent a vector as *Ae. aegypti*, but nonetheless it's still a concern for disease transmission. Besides feeding on people, it will also feed on other mammals and birds, which helps to lessen demands for resorting to people for blood meals; will usually meet its egg-producing protein needs by taking longer blood meals from a single source (person or otherwise); and while also quite common in backyards is not as likely to enter houses to feed. These are both container-breeding species common in urban and suburban settings and other developed locations too, but fortunately have flight ranges not much more than about 500 feet away from their natal origins [unlike other species such as the common saltmarsh mosquito, *Aedes sollicitans*, that typically can fly 3-5 miles inland from its coastal wetland origins in search

of blood meals, and at times up to 5-15 miles away]. But even with a relatively short flight range, anything that might increase the abundance or seasonal duration of these two problematic peridomestic species, such as warming climate, is a most unwelcomed development.

Climate change can also affect and cause shifts in local mosquito production locations at smaller scales than latitudinal effects. For example, relative sea-level rise associated with warming climate can cause a landward transgression of salt marshes into formerly upland areas, creating new production sites and habitats for larval saltmarsh mosquitoes in manner at least temporarily unknown to our field inspectors, causing treatment response problems for us. We have now seen this type of change within a period of only a few decades. Additionally, our Open Marsh Water Management (OMWM) systems, which are networks of small ponds and shallow ditches (constructed at some effort and expense to the State) that are installed in high marsh areas to help control saltmarsh mosquitoes via non- insecticidal means (relying heavily upon promotion of mosquito larvae consumption by native larvivorous killifishes), can be altered and rendered somewhat ineffective or prematurely aged by relative sea-level rise induced by warming climates.

It's also interesting to note that warming climate and mosquito-borne disease potential not only can manifest itself by latitude, but also by altitude. While altitudinal differences are of very little concern in a low-lying area such as Delaware, warming climate can cause mosquito- borne disease to occur at higher altitudes than before, essentially creeping-up mountainsides. For example, malaria is now being found in higher altitude areas of east Africa than ever before.

A changing and warming climate has tangible impacts on mosquito control operations, causing more need and more demands for our mosquito prevention or treatment services. If due to climate change our control program in future years has to become more like what now occurs in locations farther to the south, we might then be looking at a 25-50% increase in our annual program costs, including the need for more staff and operating resources. The annual budget for the Mosquito Control Section might then have to increase from its present level of about \$2 million/year up to perhaps \$2.5-3.0 million/year. Additionally, this would also result in our needing to use more insecticides to control the burgeoning mosquito populations and their problems, both for larvicides and adulticides-- environmentally this certainly would not be a good development.

But as a caveat to all of this, increases in the frequencies or abundances of mosquitoes, and for changes in their geographic ranges, shouldn't all be attributed to warming environments driven by climate change. Myriad types of human activities and their impacts on local ecology can also be major driving forces, as shown in the past for malaria, yellow fever and dengue.

Ticks

Similar as with mosquitoes, a warming climate can lead to more ticks in any given area, along with geographic range expansions northward for some species, causing more tick bites and more tick-borne diseases. With warming temperatures, everything becomes more intense and of longer duration within a year. There can be some important corollary effects from a warming climate conducive to disease problems, in then having higher populations of white-footed mice (*Peromyscus leucopus*) in woodland areas, which are a primary host reservoir for the Lyme Disease pathogen, a spirochete bacterium known as *Borrelia burgdorferi*. Black-legged or "deer" ticks (*Ixodes scapularis*) are the primary vectors for Lyme Disease, with their larval stage (after

hatching-out from eggs) feeding on white-footed mice and other rodents, and as such the larvae can pick-up the pathogen from infected small mammals. The tick's later nymphal stage will feed on humans and other larger mammals such as white-tail deer (*Odocoileus virginianus*), and in so doing infected nymphs can pass the pathogen onto people and other mammals. The adult tick stage can also take blood meals from people or other larger mammals, and in so doing if the tick is infected then pass the Lyme Disease pathogen onto their victims. Adult ticks can also initially acquire the pathogen when feeding on infected larger mammals, but are less likely to pick it up this way than in their larval or nymphal stages.

White-tail deer are the preferred source of an adult tick's final blood meal for both male and female ticks, and then also serve as mating sites for the adults, with mated females then falling off the deer to subsequently lay their eggs in forest floor soil and leaf litter. Fortunately, passage of the Lyme Disease pathogen onto tick eggs is thought to be extremely rare.

Primary concerns for tick-borne diseases in Delaware are as follows, involving 3 primary tick vectors:

- Black-legged or Deer tick (*Ixodes scapularis*) – Lyme Disease, anaplasmosis, babesiosis, ehrlichiosis, Powassan.
- American Dog tick (*Dermacentor variabilis*) – Rocky Mountain spotted fever, tularemia, tick paralysis.
- Lone Star tick (*Amblyomma americanum*) – ehrlichiosis, tularemia, STARI, Alpha-gal red meat allergy.

Anything that might increase the population abundances of these tick species, or extend or prolong their active periods throughout the year, would be of concern for human health and safety in terms of disease transmission potential. Unfortunately, a warming climate can be conducive to both greater tick abundances and their longer active presence.

An excellent example of climate change impacts on tick populations comes not from tick species that adversely affect humans, but rather this time from the animal world involving winter tick (*Dermacentor albipictus*) and moose (*Alces alces*) populations. Warming climate over the past 20 years or so is now being manifested in New Hampshire by much greater winter tick abundance, along with winter ticks being active both later into the fall and then earlier in the spring. Adult winter ticks feed upon moose, but in the past during colder climates many winter ticks would drop-off during the winter from their moose hosts or otherwise die. Unfortunately now during increasingly warmer, more mild winters, they will remain on moose throughout the winter in often very high densities adversely affecting their hosts, at times even fatally from excessive exsanguination that can greatly weaken adult moose during an already stressful cold time of year.

Better tick survival and longer periods of their contact with moose (due to milder, shorter winters) are now occurring, attributed to warmer winter temperatures.

These tick-weakened moose appear quite gaunt and lightly discolored from their loss of hair, often manifested as clear patches of skin, and have now been named "ghost moose." Newborn moose calves in late winter and early spring can be even more adversely affected by their harboring huge densities of winter ticks. Moose populations in New Hampshire have rapidly declined over the past 10 years by about 50% due to tick-caused mortalities, going from an estimated 8000-10,000 animals in the state down to only about 4000-5000 moose. This

downward crash caused by winter ticks has also been noticed in nearby Maine and Vermont, as well as in other areas to the west near southern limits of the moose's geographic range. This is a quite striking example of a warming climate favoring tick population increases, which comes at expense of their moose host populations. It's expected that moose population declines will eventually level- off at some point dictated by a newly established tick-moose population equilibrium, but the end result might be a permanently lowered moose population in southern portions of their present geographic range (which will then also have some adverse consequences for ecotourism-based economies, along with ecological impacts too).

Delaware is one of the states with a significant increase in cases of Lyme disease over the years. The Environmental Protection Agency (EPA) is concerned that climate change is playing a role. Climate is just one of many important factors that influence the transmission, distribution, and incidence of Lyme disease. That said, the life cycle and prevalence of deer ticks are strongly influenced by temperature. Deer ticks are most active when temperatures are above 45°F, and they thrive in areas with at least 85 percent humidity. Thus, warming temperatures associated with climate change are projected to increase the range of suitable tick habitat and are therefore one of multiple factors driving the observed spread of Lyme disease.

Personal Protection Measures

All told whether dealing with mosquitoes or ticks during an era of warming climate, populations of these disease- transmitting vectors will increase and benefit from warmer climes. This will come at the health expense of the species they feed upon, which of course includes people too. In addition to the measures taken by the state to control vector-borne diseases, Delawareans should protect themselves from these diseases by:

Avoidance of the vectors

For mosquitoes

- Emptying standing water from containers (to reduce opportunity for breeding)
- Installing or repairing screens on windows/doors
- Using air conditioning if available
- Mosquito netting if camping or traveling to certain areas

For ticks

- Light colored clothes
- Hat, long sleeves, long pants
- Tuck pants into socks
- Tick checks and tick removal

Use of repellents (applied in accordance with all product label instructions)

For mosquitoes

- Apply DEET (15-30%), picaridin (20%), or oil of lemon eucalyptus (30%) to skin

For ticks

- Apply DEET to skin (may be toxic in young children)

- Apply DEET or permethrin to clothing
- Use other repellents that are EPA-registered

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