REVIEW

The effect of climate change on skin disease in North America

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Global temperatures continue to rise, reaching new records almost every year this decade. Although the causes are debated, climate change is a reality. Consequences of climate change include melting of the arctic ice cap, rising of sea levels, changes in precipitation patterns, and increased severe weather events. This article updates dermatologists about the effects of climate change on the epidemiology and geographic ranges of selected skin diseases in North America. Although globalization, travel, and trade are also important to changing disease and vector patterns, climate change creates favorable habitats and expanded access to immunologically naïve hosts. Endemic North American illnesses such as Lyme disease, leishmaniasis, and dimorphic fungal infections have recently expanded the geographic areas of risk. As temperatures increase, epidemic viral diseases such as hand-foot-and-mouth disease may develop transmission seasons that are longer and more intense. Chikungunya and dengue are now reported within the southern United States, with Zika on the horizon. Cutaneous injuries from aquatic and marine organisms that have expanding habitats and longer durations of peak activity include jellyfish envenomation, cercarial dermatitis, and seabather eruption, among others. Skin cancer rates may also be affected indirectly by changes in temperature and associated behaviors. (J Am Acad Dermatol http://dx.doi.org/10.1016/j.jaad.2016.08.014.)

Key words: cercarial dermatitis; chikungunya; climate change; coccidioidomycosis; dengue; environmental change; global warming; hand-foot-and-mouth syndrome; herpangina; jellyfish; leishmaniasis; Lyme disease; seabather eruption; skin cancer; skin disease; swimmer itch; Zika.

Over the past few decades, our planet has entered a period of major changes in climate and weather patterns, almost certainly as a result of human activity.[1] Some natural fluctuations in global average surface temperatures are expected, but 17 of the warmest years on record have occurred in the past 18 years.[2] Combustion of fossil fuels and destruction of forests are the main contributors, with the latter rendering the natural world unable to maintain carbon homeostasis. These 2 activities account for up to 70% of greenhouse gas emissions,[3] which then serve to absorb infrared solar radiation in the atmosphere and trap energy that otherwise would be reflected. Climate change encompasses average planetary surface temperature and other factors that can alter species composition: temperature-related parameters (magnitude of diurnal-nocturnal temperature shifts, magnitude of annual temperature peaks and nadirs, frost dates); precipitation-related parameters (total precipitation, snowfall, seasonality, humidity); and atmospheric parameters (cloud cover; speed and direction of prevailing winds).

In 2014, the Fifth Intergovernmental Panel on Climate Change systematically reviewed the data on climate change and several high-impact medical journals published commentaries, although none emphasized skin diseases.[4-6] This article reviews publications specific to climate change and skin disease in North America.

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CHANGING DEMOGRAPHICS OF ENDEMIC DISEASES OF NORTH AMERICA

Complex biologic and abiotic environmental factors, along with human-associated alterations, influence the geographic distribution of many infectious diseases. This is especially true in temperate zones because climate change allows expansion of the natural range of pathogens, hosts, reservoirs, and vectors that allow diseases to appear in immunologically naïve populations.[7] In the United States, the incidence of Lyme disease, for example, caused by the tick-borne spirochete, *Borrelia burgdorferi*, increased from an estimated 10,000 cases/y in 1995 to 30,000/y in 2013.[8,9] The Centers for Disease Control and Prevention (CDC), however, estimates that the true incidence in the United States reached 300,000/y in 2012.[9] The area of Lyme disease's endemicity continues to expand from the New England region, where it was first identified to new areas, in conjunction with the expanding range of *Ixodes* tick vectors. The range of those ticks seems to be expanding inexorably because the preferred habitat for *Ixodes* tick and its mammalian hosts is expanding. In Canada, the area of endemism has spread from southern Quebec to Ontario, the Maritime provinces, Manitoba, and British Columbia between 1990 and 2003.[10] Although the density of *Borrelia burgdorferi* starts low when deer ticks newly inhabit an area, within 4 years *Borrelia burgdorferi* typically appears in these populations of *I scapularis*.[11]

CAPSULE SUMMARY

- There is near universal scientific agreement that the Earth is warming.
- Numerous bacteria, viruses, fungi, and parasites are responding to changing weather patterns in North America.
- Dermatologists should be able to recognize changing patterns of skin disease associated with climate change.

In the US Southwest, *Coccidioides immitis* and *C posadasii* have been historically located in hot, arid habitats of Arizona, Utah, and California. Recently, arid regions of eastern Washington state have also become endemic.[12] Consistently, the incidence of coccidioidomycosis has increased, partly because of immunologically naïve retirees who move to endemic areas, but also because longer dry seasons and more frequent wind storms aerosolize the fungal spores.[13,14] Specifically in Arizona, the annual incidence has increased from 33 to 43/100,000 population between 1998 and 2001 with climatic and environmental factors explaining 75% of the model.[15] In Kern County, California, the incidence paralleled temperature patterns, but were also influenced by environmental alterations from construction work.[16]

Dryer weather, accompanied by drought and elevated temperatures, has resulted in significantly increased rates, increased geographic range, and increased infectious cycles of leishmaniasis.[17,18] Habitat fragmentation and deforestation also play a role in increased prevalence of the disease and vector.[19] Using well-established climate models, researchers have shown an expansion of competent sand fly vectors into areas farther from the equator.[20] Autochthonous transmission already has a foothold along the United States-Mexican border states because the presence of both an established rodent reservoir for *Leishmania mexicana* and competent sand fly vectors, *Lutzomyia diabolica* and *Lutzomyia anthrophora*, permits a local transmission cycle.[21] Both the rodent reservoir and sand fly are expected to bring *Leishmania* species (spp) northward, potentially even to the United States-Canadian borderlands by 2080.[21]

Hand-foot-and-mouth disease is a classic seasonal enteroviral infection in temperate climates. The incidence correlates with the average temperature and average rainfall.[22] Similar associations with increased average temperature have been shown in an urban population with hand-foot-and-mouth disease, and even stronger associations with another enteroviral infection, herpangina.[23] Using predictive modeling, an increase in weekly average air temperature by 2°C, 2 days per week, will increase the incidence of herpangina by 43%.[23] Humidity is another climate variable associated with epidemics of hand-foot-and-mouth disease.[24]

Dermatologists should be aware of changing seasons and locations along with the typical clinical findings of diseases that are already well established in North America (Supplemental Table I also includes Chagas disease).

ARBOVIRAL DISEASE

Mosquito vectors are unwittingly transported to new geographic footholds through the global used-tire and used-car trade.[25] Dengue, chikungunya, and Zika viruses are spread by the *Aedes aegypti* and *A albopictus* mosquitos. These invasive mosquitos, originally from Africa and Asia, respectively, have spread widely throughout North America.

Chikungunya, caused by a togavirus, can cause severe joint pain, high fever, and a morbilliform