The ecology of climate change and infectious diseases: comment

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Kevin Lafferty argues “... that while climate has affected and will continue to affect the habitat suitability for infectious diseases, climate change seems more likely to shift rather than expand [their] geographic ranges...” (Lafferty 2009).

There are several problems with this argument. One involves the definition of climate change; the next concerns the non-uniformity of global warming, in space and time; and the third area is the breadth of concerns.

First, climate change is not just a change in the global temperature; it is also a change in the weather. While temperatures affect the potential ranges of infectious diseases and their vectors, weather affects the timing, intensity and location of outbreaks. As warming occurs, weather patterns are shifting, with more extremes of both signs (hot and cold, wet and dry), more major outliers, and the appearance of novel events (e.g., a hurricane in the Southern Atlantic). Indeed, the distribution no longer resembles a Gaussian bell-shaped curve, but appears to be becoming more bimodal, with more extremes at both ends.

With regard to extreme weather events (EWEs), Lafferty addresses the associations between the El Niño/Southern Oscillation (ENSO) and disease outbreaks. But ENSO is not synonymous with EWEs, which are on the rise independent of ENSO. This is primarily attributable to the physics of global warming: since 1957, the world ocean has accumulated 22 times as much heat as has the atmosphere (Barnett et al. 2005, Levitus et al. 2005), accelerating the global hydrological cycle. (And a warmer atmosphere holds more water vapor: 7% more for each 1°C it warms.) Heavy rains can create floodplains where mosquitoes breed, as in the outbreaks of Rift Valley fever in East Africa (Linthicum et al. 1999, Anyamba et al. 2009). And storms, floods and droughts can create conditions conducive to “clusters” of water-, mosquito- and rodent-borne diseases (Epstein 1999, Relman et al. 2008). (One can only project conditions conducive to outbreaks; their appear-
Moreover, growing weather instability is breeding sequences of extremes (e.g., droughts, punctuated by heavy rains; series of strong hurricanes), and these can be particularly conducive to disease outbreaks. Mozambique in 2000, for example, in a span of six weeks, experienced three cyclones and incessant heavy rains, leading to widespread flooding and a five-fold spike in malaria in the affected regions (Epstein and Mills 2005).

The sequences of extremes can be especially destabilizing to the ecological (predator–prey and competitor) relationships critical to the control of pests (especially mosquitoes and rodents) that can carry pathogens (Molyneux et al. 2008).

The issue of EWEs and their consequences for health and public welfare, social systems and adaptation to the coming climate is now being formally addressed by the IPCC and by international relief agencies, such as the International Federation of Red Cross and Red Crescent Societies (2007). In the coming climate, changing weather patterns may have more to do with the distribution of outbreaks than will the rise in average global temperatures.

Regarding the rise in temperature, itself, warming is not occurring evenly across the globe, both spatially and temporally. Warming is occurring disproportionately closer to the poles; i.e., temperate, boreal, and arctic regions are warming faster than are the tropics. While average global temperatures rose about 1.4°F (0.8°C) during the past century, for instance, average annual temperatures in Alaska increased 3.1°F (1.9°C) from 1950 to 2006, and, consistent with global trends, the average winter temperature increased 6°F (3.3°C) in the same time frame (Demain et al. 2009; Alaska Climate Research Center, data available online).2 Vectors and microbes are thus experiencing less differential warming in their lower latitude ranges than they are at higher latitudes.

Temporally, since 1970, nighttime and winter temperatures (i.e., daily and yearly minimum temperatures [TMINs]) have risen twice as fast as overall warming (Easterling et al. 1997). And winter warming is most pronounced as one moves toward the poles. TMINs, not temperature averages, are critical to the biological responses to global warming. Paleo (fossil) records of beetle distributions in Europe and North America demonstrate, for example, that their distribution changed in consort with changes in TMINs. The Younger Dryas (YD)—the most well-known of the many “cold reversals” to punctuate warming trends depicted in the ice core records (the YD occurred some 13,000 years ago)—is precisely delineated by changes in the distribution of beetle communities (Elias 1994; mapping reproduced in Epstein et al. 1998).

Regarding tick populations, Lafferty states “…the best predictor of changes in TBE [tick-borne encephalitis] from 1970 to 2005 is poverty ….” While this may be so—and all outcome measures can be traced to a suite of social and environmental determinants—Lindgren and Gustafson (2001) demonstrate that TBE-bearing tick populations moved north in Sweden in lockstep with each warm winter. And there appears to be no diminution of tick populations at the southern region of their expanding range. Indeed, their maps indicate that tick populations increased in abundance in the area of their former distribution, centered on the Stockholm Archipelago.

Regarding projections for tick populations, Brownstein and colleagues (2005) model suitable U.S. habitat out to 2080 for Borrelia burgdorferi-bearing ticks (also capable of carrying several viruses and the agents of Ehrlichiosis and Babesiosis). Data, however, suggest that changes in range are occurring much faster than the models project, with the rise in TMINs at high temperate and boreal latitudes the most plausible explanation.

Forest pests are also expanding their range. In the western United States from Arizona to Alaska, pine bark beetles are overwintering, moving to higher latitudes, higher altitudes, and getting in more generations each year, absent sustained killing frosts, e.g., when temperatures fall below 20°F (approximately −7°C) for 10 days. But their numbers and the damage they are doing have not diminished in the southern range or at lower altitudes (Van Sickle 1995, Carroll et al. 2004, Solomon et al. 2007). Host (tree) resistance is also lowered by extremes: repeated droughts dry the resin that drowns the beetles as they try to drive through the bark. In the northeast United States, the aphid-like wooly adelgid is decimating the Eastern Hemlock trees and is moving north after doing its damage at its southern range, while the Asian longhorned beetle threatens maple and other deciduous trees.

Such biological impacts of warming and extremes on vectors and pathogens, the warmth and drying can produce unexpected results. Lafferty and other authors in the same issue of Ecology (Harvell et al. 2009, Pascual and Bouma 2009) address potential changes in the distribution of animal hosts and reservoirs. People can also move in response to changing environmental conditions.
conditions. In southern Honduras, for example, conditions have become so hot and the hydrological cycle so altered (as a result of warming, deforestation and the destruction of coastal mangroves to make way for shrimp farming), that malaria is no longer a significant health threat in the region around Choluteca. But, concomitant loss of agricultural productivity and the advancing water shortages have driven human populations north, where monoculture plantations and fragmented forests provide employment and favorable conditions for malaria transmission.

Notably, malaria did spike even in the less-populated south when Hurricane Mitch stalled over Honduras in November, 1998, dropping six feet of rain over three days.

On the other hand, droughts, which Lafferty states do not contribute to infectious disease distribution, are associated with a number of infectious ills. Droughts, when people store water in containers about their houses, are associated with upsurges of *Aedes aegypti* mosquitoes, and outbreaks of dengue fever in the Caribbean and chikungunya fever in East Africa and Indian Ocean islands (Epstein 2007, Chrétien et al. 2007). For West Nile fever, a prolonged spring drought and a three-week July heat wave that preceded its explosive debut in Queens, New York in August 1999, appear to have amplified viral circulation: increasing the abundance of catch-basin-dwelling *Culex pipiens* (the maintenance vector) and viral replication in the mosquitoes and birds (Epstein and Defilippo 2001). (Now, with West Nile virus well established in wildlife in the United States, warm wet conditions are conducive to outbreaks.) In the African Sahel, meningococcal meningitis epidemics tend to occur during drought (Moore and Broome 1994), the dried mucus membranes perhaps playing a role in bacterial penetration. Several agricultural pests—aphids, locust and geminivirus-injecting whiteflies—flourish during droughts, while floods foster fungal growth and the proliferation of nematodes.

Lafferty addresses changes in marine-related diseases, and has written about the mounting threats of warming and diseases in coral reefs (Lafferty et al. 2004). But several diseases of other marine organisms suggest that ranges of diseases may be extending. Dermo and MSX, for example, are two parasitic diseases that have severely crippled oyster populations along the U.S. east coast. And while they have moved up the coast into New England from where they first appeared (in Chesapeake Bay)—again moving with each warm winter—they are also spreading south (Hofmann et al. 2001). Another shell-fish resident, *Vibrio parahaemolyticus*, caused an outbreak in humans consuming raw oysters from a local shell-fish farm after daily water temperatures exceeded 15°C (McLaughlin et al. 2005). The authors concluded that “This investigation extends by 1000 km the northernmost documented source of [oyster-related] *V. parahaemolyticus* in the U.S.” While complete data on distribution of this bacteria are not readily available, there is no reason to believe that *V. parahaemolyticus* has left tropical climes, where ocean temperatures have not experienced the same degree of warming as have those (periodically, for sure) at higher latitudes.

Climate and ecological models, monitoring and mapping can be employed to address the pests and pathogens afflicting forests, crops, livestock, wildlife and marine life (Relman et al. 2008). The combination of warming, unstable weather patterns (e.g., early heat waves coinciding with flowering), rising CO₂ that favors weeds over crops (Ziska et al. 2009), and changes in the ranges and abundance of pests and pathogens pose mounting threats for the health and integrity of ecosystems.

In sum, our health, the final common pathway integrating our environmental and social surroundings, is threatened in multiple ways by growing climate instability. Warming-induced range shifts, expansion and spread of specific infectious diseases are part of a much larger landscape of climate-related impacts on the emergence, resurgence and redistribution of infectious diseases occurring across a wide range of taxonomic groups on a global scale. Unchecked, climate change poses fundamental threats for our health and for the health of the life-support systems upon which we depend.

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**Literature cited**


