HHR
Health and Human Rights Journal

# Chikungunya, Climate Change, and Human Rights

BRADEN MEASON AND RYAN PATERSON

## Abstract

Chikungunya is a re-emerging arbovirus that causes significant morbidity and some mortality. Global climate change leading to warmer temperatures and changes in rainfall patterns allow mosquito vectors to thrive at altitudes and at locations where they previously have not, ultimately leading to a spread of mosquito-borne diseases. While mutations to the chikungunya virus are responsible for some portion of the re-emergence, chikungunya epidemiology is closely tied with weather patterns in Southeast Asia. Extrapolation of this regional pattern, combined with known climate factors impacting the spread of malaria and dengue, summate to a dark picture of climate change and the spread of this disease from south Asia and Africa into Europe and North America. This review describes chikungunya and collates current data regarding its spread in which climate change plays an important part. We also examine human rights obligations of States and others to protect against this disease.

Braden Meason, MD, is Resident Physician in Emergency Medicine at Denver Health Medical Center, Denver, CO, USA.

Ryan Paterson, MD, DTM&H, is Staff Physician in Emergency Medicine for the Kaiser Permanente Group in Denver, Colorado, USA, and Assistant Professor in the Department of Emergency Medicine at the University of Colorado/Denver Health Medical Center.

Please address correspondence to the authors c/o Ryan Paterson. Email: ryan.paterson@ucdenver.edu.

Competing interests: None declared.

## Background

Chikungunya is a re-emerging arboviral disease spread by mosquito vectors. The disease itself is characterized by fever, severe myalgias and arthralgias, dermatologic manifestations, and frequently chronic arthritis. Sometimes clinically difficult to distinguish from dengue fever, its first strains were isolated in the eastern African nation of Tanzania (formerly Tanganyika) in 1952. At the time, an outbreak of febrile illness similar to dengue was observed affecting the Makonde people, but dengue was not isolated as the causative agent. Further investigation revealed a novel arbovirus, which was named "chikungunya." The name originates from the native Makonde language and means "that which bends up," referring to the bodily contortions associated with the characteristic severe arthralgias.[1] Descriptions of febrile illness outbreaks prior to the isolation of chikungunya in 1952 suggest that the disease has been present in Africa and southeast Asia since 1779, though such outbreaks had previously been attributed to dengue.[2]

Subsequent to its discovery, chikungunya is known to have caused episodic outbreaks in Africa, India, and southeast Asia, spreading to Indonesia by the 1980s.[3] The frequency and severity of outbreaks in the Indian Ocean region then dropped off dramatically.[4] Chikungunya continued to cause intermittent epidemics in southeast Asia from the 1960s to 2003, and has been endemic in Africa since the 1980s.[5] The most recent epidemic began in Kenya in 2004, quickly spreading to the islands of the Indian Ocean, and by 2005 had caused disease in at least 1 million people in the region.[6] During this period, though millions had been affected, few outside of infectious disease and travel medicine circles were aware of chikungunya, possibly because the disease was only affecting peoples of less developed nations. It wasn't until 2005 when an outbreak began on the French island of Réunion in the southwest Indian Ocean and spread to India that the world's medical communities began to take notice. The 2005 outbreak ultimately affected 255,000 people in Réunion and at least 1.4 million people in India.[7]

## Clinical syndrome

The 2005 outbreak on Réunion not only heightened awareness of chikungunya, but also highlighted changes in the epidemiology and clinical syndrome of the illness. Historically, chikungunya was recognizable by the abrupt onset of high fever lasting one to seven days with crippling myalgias and lower back pain. Severe arthralgias of the ankles and wrists as well as conjunctivitis and a maculopapular rash were common. Occasionally, the virus caused more severe mucous membrane and dermatologic manifestations, including bullae and sloughing. The onset of symptoms often occurs two to six days after inoculation by an infected mosquito, and infectious bites have nearly a 100% transmission rate.[8] Chikungunya was rarely fatal, and complete recovery was expected, although some people did experience chronic arthritis following the acute infection.[9]

In contrast, during the Réunion outbreak, the clinical presentations were more severe. This included vertical maternal-infant transmission, meningoencephalitis, hepatic failure, spontaneous hemorrhage due to thrombocytopenia, and an increased number of deaths in patients at the extremes of age or with other co-morbid conditions.[10] The overall mortality rate was estimated to be between 0.3 and 1 in 1,000 symptomatic cases, much higher than in any other known chikungunya epidemic.[11] Chronic persistent arthritis was reported in as many as 93.7% of patients and has led to significant disability and large public health and economic burdens.[12] Even two years later, up to 75% of infected individuals continued to complain of symptoms attributable to chikungunya.[13] These effects of chikungunya were most apparent in regions without access to adequate healthcare, disproportionately impacting less developed communities.[14]

## Vector epidemiology

The Réunion epidemic also demonstrated a change in the predominant mosquito vector. In Asia, chikungunya was generally associated with the *Aedes (Stegomyia) aegypti* mosquito in a mosquito-human-mosquito life cycle. In Africa, it was associated with multiple *Aedes* species, not including *albopictus* or *aegypti*, and involved non-human primates in a sylvatic cycle.[15] During the Réunion outbreak however, low numbers of *A. aegypti* and large numbers of *Aedes (Stegomyia) albopictus* mosquitoes present on the island suggested a vector switch.[16] Genetic studies of the virus in Réunion confirmed this hypothesis, and outbreaks in Europe and Gabon likewise demonstrated that *A. albopictus* was now spreading chikungunya.[17] Such a vector switch greatly expands the available range of chikungunya and carries enormous ramifications regarding the epidemic potential and global spread of this arbovirus.

The *A. albopictus* mosquito, with its flexibility in breeding sites, covers substantially larger portions of the globe than *A. aegypti*, including both coasts of North America, parts of southern Europe, and large portions of South America in addition to Africa and southern Asia.[18] The global range of this new vector and its potential for human-mosquito-human transmission has seen the introduction of chikungunya to Italy, where an outbreak occurred in 2007. The presumed index case was a returning traveler who developed fever two days after arriving from India, where he likely contracted the disease. Subsequently, there were 205 cases confirmed in Italy, all from presumed human-mosquito-human spread without a non-human reservoir.[19] Sporadic cases of chikungunya have been identified in other parts of Europe and North America. The majority of these cases have occurred in returning travelers; however, a few cases of autochthonous transmission have now been reported in southeast France.[20] As *A. albopictus* mosquitoes spread to cover the globe, the potential for chikungunya endemicity is real.[21]

## Treatment and prevention

Due to the increasing global threat of chikungunya, further treatments and significant locally driven prevention strategies are needed. The chronic arthritis is frequently extremely painful, and some investigators have found evidence of erosive and destructive disease similar to rheumatoid arthritis.[22] So far, the most promising treatments are non-steroidal anti-inflammatory medications, disease modifying anti-rheumatic drugs, and immunosuppressants, though no large trials utilizing these have been carried out. In India, chloroquine was found to be ineffective in treating the chronic manifestations of chikungunya arthritis, and corticosteroids should be avoided as they appear to cause significant rebound symptoms when stopped.[23] Aspirin should not be used due to the risk of bleeding in the setting of thrombocytopenia.

Ultimately, the best treatment is prevention. Since the 1960s, a number of chikungunya vaccine candidates have been developed and tested, although these efforts have yet to yield a licensed vaccine.[24] Without a vaccination, vector control and bite-prevention strategies are the only alternatives. Reduction in the numbers of *A. albopictus* may be possible with significant local community efforts, but there are many barriers to effective vector control.[25] *A. albopictus* will breed in nearly any water supply and has an extremely rapid life-cycle, so control measures require at least weekly emptying and cleaning of every available standing water source. In addition, *A. albopictus* is aggressive and active during the early morning and late afternoon, meaning traditional night-time-only bite-prevention methods such as bed nets will not significantly decrease bite rates.[26] Prevention also requires resources that low-income communities may lack, leaving them at increased risk for exposure.

## Re-emergence and climate change

Understanding why chikungunya has re-emerged on a global scale may offer some clues to future prevention of such large epidemics. Novel mutations in the virus genome are likely contributing to increased virulence, severity of disease, and affinity for the new *A. albopictus* vector, leading to larger and more severe outbreaks.[27] In addition to these mutations, low herd immunity and changes in local environmental factors that allow for increases and changes in mosquito vectors all set the stage for widespread disease.[28]

An increasing percentage of the world's population is living in cities. *A. aegypti* thrives in urban areas, while *A. albopictus* lives in both urban and rural settings. With such anthropophilic mosquitoes, human activity is linked to their survival and may even promote breeding.[29] During drought conditions, people maintain water stores for long periods of time and are less likely to replenish or clean storage containers on a regular basis.[30] These water conservation practices during drought lead to increased mosquito breeding, and have been implicated in the outbreak of disease.[31] For example, the outbreak that Kenya experienced in 2004 occurred after long periods of drought, which were the driest since 1998.[32]

In rainy periods, mosquito reproduction relies on small pools and ponds. During an epidemic in central Thailand, chikungunya infection followed periods of heavy rainfall by approximately six weeks.[33] It is intriguing that increased populations of *Aedes* mosquitoes and related chikungunya infection can be seen during periods of drought, as well as following heavy rains. Climate change is pushing weather patterns to these extremes. Recent trends show increased periods of drought in the tropics, as well as increased rainfall in temperate areas, with episodes of heavier precipitation in both regions.[34] The chikungunya re-emergence is complex and multifactorial, but it appears, in part, to follow the weather patterns that are associated with global climate change.

On a larger scale, climate change increases the global habitat available to mosquitoes by increasing average temperatures and periods of heavy precipitation.[35] In northern Italy and the Alps, increases of approximately one degree centigrade per century have allowed for habitat expansion of *A. albopictus*.[36] Central and South America are already home to *A. albopictus*, and in the United States, *A. albopictus* territories are expanding along the East and West Coast.[37] Most predictive models of *A. albopictus* habitat expansion anticipate continued invasion into historically more temperate areas with progressive climate change.[38]

Climate change and its accompanying natural disasters are verifiable and increasing worldwide. While hurricanes, floods, and extreme temperatures make the news, subtle changes in weather patterns carry grave implications for mosquito-borne illness.[39] As for malaria, dengue, and parasitic diseases that are closely tied to human activities and climate change, chikungunya also demonstrates a close relationship with changes in precipitation.[40] As drought and heavy rainfall events increase with climate change and disease vectors spread, chikungunya prevalence is likely to increase, with the possibility of becoming endemic worldwide.[41]

## Chikungunya, the economy, and public health

Due to its subsequent chronic arthritis, chikungunya carries significant economic and public health considerations. The overall cost of the Réunion outbreak is estimated at more than €60 million ($80 million USD), with simple direct medical costs of €60 to €120 ($80 to $160 USD) per case.[42] This is nearly double the per-case cost calculated during an epidemic of dengue in Cambodia from 2006 to 2008, and does not account for the chronic sequelae associated with chikungunya infection.[43] With such a prolonged and severe post-infection course, the economic, medical, and social burden on a community can be extreme.

Not only does chikungunya cause chronic health concerns, it disproportionately affects lower socioeconomic and less well-educated populations.[44] In low-income areas of India, during the 2006 epidemic, the productivity losses due to foregone income are estimated to have cost 391 million rupees ($5.5 million USD) for the year, primarily due to chronic arthritis.[45] The estimated burden in disability-adjusted life years (DALY) was as high as 25,588 DALY for a single outbreak in India in 2006.[46] In one Indian village where daily wages averaged from $0.60 to $1.70 USD, the estimated cost per case during the epidemic was $37.50 USD, or the equivalent of two months' pay.[47] Diseases such as chikungunya carry costs that are disproportionately burdensome for people living in poverty.[48]

## Discussion

As climate change increases global temperatures and causes more extreme weather patterns, the health and financial burden of chikungunya will worsen. Presently, people already living in poverty or who are not educated are more vulnerable to this disease. There are human rights obligations, firstly on the States in which chikungunya is present, to protect the most vulnerable and disadvantaged communities from the disease. In particular, education and information campaigns are needed so that communities can take whatever prevention measures possible to lower their risk to the vectors. It can also be argued that States should call on international states to assist them in addressing the spread of the disease. Not only are the international human rights legal obligations on international states clearly articulated in UN General Comment 14 (2000), but from a public health perspective, it is in the public health interest of international states to lessen the risk of global spread of chikunyunga.[49]

Climate change and its associated diseases are presenting new risks to everyone's rights to life and health, irrespective of where they live. Without a functional, livable, healthy ecosystem, drought and famine increase, diseases spread, and people's rights are challenged. As periods of drought and rainfall increase, more extreme weather events are recorded and ecosystems change. When ecosystems change and vector habitats subsequently enlarge, diseases spread. When diseases spread, health and life are placed in jeopardy and people from low-resource areas are most at risk. Cost analysis reports of chikungunya demonstrate a disproportionate burden of disease experienced by resource-poor versus resource-rich communities. Their vulnerability and marginalized status requires that States fulfill their human rights duties to address their health risks as soon as possible. Currently, States are failing to meet their right to health obligations as described by the International Covenant on Economic, Social and Cultural Rights, and General Comment 14, to address the causes of chikungunya.[50]

We believe the medical community also carries human rights duties to take action to help mitigate climate change and to protect vulnerable people who will suffer the impacts of emerging epidemics. As a global community, in conjunction with state governments, we must develop and enact a plan to address climate change and raise awareness of the close link between such change and diseases like chikungunya.

## References

1. M. Robinson, "An epidemic of virus disease in southern province, Tanganyika territory, in 1952–1953," *Transactions of the Royal Society of Tropical Medicine* 49/1 (1955), pp. 28–32; P. Mason, A. Haddow, "An epidemic of virus disease in Southern Province, Tanganyika Territory, in 1952–1953: An additional note on Chikungunya virus isolations and serum antibodies," *Transactions of the Royal Society of Tropical Medicine* 51/3 (1957), pp. 238–240; W. Lumsden, "An epidemic of virus disease in Southern Province, Tanganyika territory, in 1952–1953 II. General description and epidemiology," *Transactions of the Royal Society of Tropical Medicine* 49/1 (1955), pp. 33–57.

2. J. S. Mackenzie, K. B. Chua, P. W. Daniels et al. "Emerging viral diseases of Southeast Asia and the Western Pacific," *Emerging Infectious Diseases* 7/Suppl 3 (2001), pp. 497–504; S. K. Singh, S. K. Unni, "Chikungunya virus: host pathogen interaction," *Reviews in Medical Virology* 21/2 (2011), pp. 78–88.

3. S. W. Brighton, O. W. Prozesky and A. L. de la Harpe, "Chikungunya virus infection. A retrospective study of 107 cases," *South African Medical Journal* 63/9 (1983), p. 313–5; F. M. Rodrigues, M. R. Patankar, K. Banerjee et al. "Etiology of the 1965 epidemic of febrile illness in Nagpur city, Maharashtra State, India," *Bulletin of the World Health Organization* 46/2 (1972), pp. 173–179.

4. K. Pavri, "Disappearance of chikungunya virus from India and South East Asia," *Transactions of the Royal Society of Tropical Medicine* 80/3 (1986), p. 491.

5. A. M. Powers and C. H. Logue, "Changing patterns of

chikungunya virus: re-emergence of a zoonotic arbovirus," *The Journal of General Virology* 88/9 (2007), pp. 2363–2377.

6. D. Sissoko, D. Malvy, C. Giry et al. "Outbreak of Chikungunya fever in Mayotte, Comoros archipelago, 2005-2006," *Transactions of the Royal Society of Tropical Medicine and Hygiene* 102/8 (2008), pp. 780–786; K. Sergon, A. A. Yahaya, J. Brown et al., "Seroprevalence of Chikungunya virus infection on Grande Comore Island, union of the Comoros, 2005," *The American Journal of Tropical Medicine and Hygiene* 76/6 (2007), pp. 1189–1193; A. A. Yoosuf, I. Shiham, A. J. Mohamed et al. "First report of chikungunya from the Maldives," *Transactions of the Royal Society of Tropical Medicine and Hygiene* 103/2 (2009), pp. 192–196; World Health Organization, "Outbreak and spread of chikungunya," *Weekly epidemiological record* 47/82 (2007), p. 409–416; C. Lahariya and S. Pradhan, "Emergence of chikungunya virus in Indian subcontinent after 32 years: a review," *Journal of Vector Borne Diseases* 43/4 (2006), pp. 151–160.

7. World Health Organization, "Chikungunya and Dengue in the south west Indian Ocean," Available at: http://www.who.int/csr/don/2006_03_17/en/; P. Renault, J-L. Solet, D. Sissoko et al. "A Major Epidemic of Chikungunya Virus Infection on Réunion Island, France, 2005–2006," *The American Journal of Tropical Medicine and Hygiene* 77/4 (2007), pp. 727–731; G. Pialoux, B-A. Gaüzère, S. Jauréguiberry et al. "Chikungunya, an epidemic arbovirosis," *The Lancet Infectious Diseases* 7/5 (2007), pp. 319–327.

8. F. J. Burt, M. S. Rolph, N. E Rulli et al. "Chikungunya: a re-emerging virus" *The Lancet* 379/9816 (2012), pp. 662–671.

9. Robinson (see note 1); Rodrigues (see note 3).

10. P. Gérardin, G. Barau, A. Michault et al. "Multidisciplinary prospective study of mother-to-child chikungunya virus infections on the island of La Réunion," *PLoS Medicine* 5/3 (2008), p. e60; A. Economopoulou, M. Dominguez, B. Helynck et al. "Atypical Chikungunya virus infections: clinical manifestations, mortality and risk factors for severe disease during the 2005-2006 outbreak on Réunion," *Epidemiology and Infection* 137/4 (2009), pp. 534–541; G. Borgherini, P. Poubeau, F. Staikowsky et al. "Outbreak of chikungunya on Réunion Island: early clinical and laboratory features in 157 adult patients," *Clinical Infectious Diseases* 44/11 (2007), pp. 1401–1407; Renault (see note 7).

11. Ibid; Burt (see note 8).

12. M. Enserink, "Massive outbreak draws fresh attention to little-known virus," *Science* 311/5764 (2006), p. 1085; F. Paganin, G. Borgherini, F, Staikowsky et al. "Chikungunya on Réunion Island: chronicle of an epidemic foretold," *Presse médicale* 35/4 (2006), pp. 641–646; B. Queyriaux, F. Simon, M. Grandadam et al. "Clinical burden of chikungunya virus infection," *The Lancet Infectious Diseases* 8/1 (2008), pp. 2–3.

13. P. Gérardin, A. Fianu, D. Malvy et al. "Perceived morbidity and community burden after a Chikungunya outbreak: the TELECHIK survey, a population-based cohort study," *BMC Medicine* 9/1 (2011), p. 5.

14. Ibid; M-K. Soumahoro, P-Y. Boelle, B-A. Gaüzere et al. "The Chikungunya epidemic on La Réunion Island in 2005-2006: a cost-of-illness study," *PLoS Neglected Tropical Diseases* 5/6 (2011), p. e1197; S. S. Gopalan and A. Das, "Household economic impact of an emerging disease in terms of catastrophic out-of-pocket health care expenditure and loss of productivity: investigation of an outbreak of chikungunya in Orissa, India," *Journal of Vector Borne Diseases* 46/1 (2009), pp. 57–64; K. Krishnamoorthy, K. T. Harichandrakumar, A. Krishna Kumari, et al. "Burden of chikungunya in India: estimates of disability adjusted life years (DALY) lost in 2006 epidemic," *Journal of Vector Borne Diseases* 46/1 (2009), pp. 26–35; T. Seyler, Y. Hutin, V. Ramanchandran et al. "Estimating the burden of disease and the economic cost attributable to chikungunya, Andhra Pradesh, India, 2005-2006," *Transactions of the Royal Society of Tropical Medicine and Hygiene* 104/2 (2010), pp. 133–138.

15. B. Sudeep and D. Parashar, "Chikungunya: an overview," *Journal of Biosciences* 33/4 (2008), pp. 443–449.

16. I. Schuffenecker, I. Iteman, A. Michault et al. "Genome microevolution of chikungunya viruses causing the Indian Ocean outbreak," *PLoS Medicine* 3/7 (2006), p. e263; R. N. Charrel, X. de Lamballerie, and D. Raoult, "Chikungunya outbreaks-the globalization of vectorborne diseases," *The New England Journal of Medicine* 356/8 (2007), pp. 769–771.

17. Enserink (see note 12); G. Rezza, L. Nicoletti, R. Angelini, et al. "Infection with chikungunya virus in Italy: an outbreak in a temperate region," *The Lancet* 370/9602 (2007), pp. 1840–1846; F. Pagès, C. N. Peyrefitte, M. T. Mve et al. "Aedes albopictus mosquito: the main vector of the 2007 Chikungunya outbreak in Gabon," *PLoS One* 4/3 (2009), p. e4691.

18. M. Q. Benedict, R. S. Levine, W. A. Hawley et al. "Spread of the tiger: global risk of invasion by the mosquito Aedes albopictus," *Vector Borne and Zoonotic Diseases* 7/1 (2007), pp. 76–85.

19. Rezza (see note 17).

20. M. Grandadam, V. Caro, S. Plumet et al. "Chikungunya virus, southeastern France," *Emerging Infectious Diseases* 17/5 (2011), pp. 910–913.

21. Charrel (see note 16).

22. S. P. Manimunda, P. Vijayachari, R. Uppoor et al. "Clinical progression of chikungunya fever during acute and chronic arthritic stages and the changes in joint morphology as revealed by imaging," *Transactions of the Royal Society of Tropical Medicine and Hygiene* 104/6 (2010), pp. 392–399.

23. A. Savarino, L. Di Trani, I. Donatelli et al. "New insights into the antiviral effects of chloroquine," *The Lancet Infectious Diseases* 6/2 (2006), pp. 67–69; A. Chopra, M. Saluja and A. Venugopalan, "Chloroquine effectiveness and inflammatory cytokine response in early persistent post chikungunya musculoskeletal pain and arthritis," *Arthritis and Rheumatism* 66/2 (2014), pp. 319-126; S-D. Thiberville, N. Moyen, L. Dupuis-Maguiraga et al. "Chikungunya fever: Epidemiology, clinical syndrome, pathogenesis and therapy," *Antiviral Research* 99/3 (2013), pp. 345–370.

24. S. C. Weaver, J. E. Osorio, J. A. Livengood et al. "Chikungunya virus and prospects for a vaccine," *Expert Review of Vaccines* 11/9 (2012), p. 1087–101.

25. M. Nelder, B. Kesavaraju, A. Farajollahi et al. "Suppressing Aedes albopictus, an emerging vector of dengue and chikungunya viruses, by a novel combination of a monomolecular film and an insect-growth regulator," *The American Journal of Tropical Medicine and Hygiene* 82/5 (2010), pp. 831–837.

26. W. A. Hawley, "The biology of Aedes albopictus," *Journal of the American Mosquito Control Association* 1/Suppl (1988), pp. 1–39.

27. Schuffenecker (see note 16); B. Mishra and R. K. Ratho, "Chikungunya re-emergence: possible mechanisms," *The Lancet* 368/9539 (2006), p. 918.

28. Pavri (see note 4).

29. L. Nguyen, A. Clements, J. Jeffery et al. "Abundance and prevalence of Aedes aegypti immatures and relationships with household water storage in rural areas in southern Viet Nam," *International Health* 3/2 (2011), pp. 115–125.

30. R. Subra, "The regulation of preimaginal populations of Aedes aegypti L. (Diptera: Culicidae) on the Kenya coast. I. Preimaginal population dynamics and the role of human behaviour. *Annals of Tropical Medicine and Parasitology* 77/2 (1983), p. 195–201.

31. Nguyen (see note 29); J-P. Chretien, A. Anyamba, S. A. Bedno et al. "Drought-associated chikungunya emergence along coastal East Africa," *The American Journal of Tropical Medicine and Hygiene* 76/3 (2007), pp. 405–407; M. N. Islam, M. Zulkifle, A. M. Sherwani et al. "Prevalence of malaria, dengue, and chikungunya significantly associated with mosquito breeding sites," *Journal of the Islamic Medical Association of North America* 43/2 (2011), pp. 58–67.

32. Ibid.

33. T. Ditsuwan, T. Liabsuetrakul, V. Chongsuvivatwong et al. "Assessing the spreading patterns of dengue infection and chikungunya fever outbreaks in lower southern Thailand using a geographic information system," *Annals of Epidemiology* 21/4 (2011), pp. 253–261.

34. K. E. Trenberth, P. D. Jones, P. Ambenje et al. "Observations: Surface and Atmospheric Climate: contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change," in: D. Qin , M. Manning, Z. Chen, M. Marquis, K.B. Averyt, and M. Tignor, eds. *IPCC Fourth Assessment Report: Climate Change 2007: The Physical Science Basis* (Cambridge, UK: Cambridge University Press, 2007).

35. L. Bai, L. C. Morton, Q. Liu, "Climate change and mosquito-borne diseases in China: a review," *Globalization and Health* 9/1 (2013), p. 10; S. H. Lee, K. W. Nam, J. Y. Jeong et al. "The effects of climate change and globalization on mosquito vectors: evidence from Jeju Island, South Korea on the potential for Asian tiger mosquito (Aedes albopictus) influxes and survival from Vietnam rather than Japan," *PLoS One* 8/7 (2013), p. e68512; L. Eisen and C. G. Moore, "Aedes (Stegomyia) aegypti in the continental United States: a vector at the cool margin of its geographic range," *Journal of Medical Entomology* 50/3 (2013), pp. 467–78.

36. D. Roiz, M. Neteler, C. Castellani et al. "Climatic factors driving invasion of the tiger mosquito (Aedes albopictus) into new areas of Trentino, northern Italy," *PLoS One* 6/4 (2011), p. e14800.

37. I. Rochlin, D. V. Ninivaggi, M. L. Hutchinson et al. "Climate change and range expansion of the Asian tiger mosquito (Aedes albopictus) in Northeastern USA: implications for public health practitioners," *PLoS One* 8/4 (2013), p. e60874.

38. F. Schaffner, G. Hendrickx, E. Scholte, "Development of Aedes albopictus risk maps," *European Centre for Disease Prevention and Control* (May 2009); Benedict (see note 18).

39. U. Confalonieri, B. Menne, T. Akhtar et al. "Human health. Climate Change 2007: impacts, adaptation and vulnerability: contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change," in: M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, C.E. Hanson, eds. *IPCC Fourth Assessment Report: Climate Change 2007* (Cambridge, UK: Cambridge University Press, 2007), pp. 391–431.

40. U. E. C. Confalonieri, C. Margonari, A. F. Quintão, "Environmental change and the dynamics of parasitic diseases in the Amazon," *Acta Tropica* 129 (2014), pp. 33-41; Eisen (see note 35).

41. R. Dhiman, S. Pahwa, G. Dhillon et al. "Climate change and threat of vector-borne diseases in India: are we prepared?" *Parasitology Research* 106/4 (2010), pp. 763–773; Nguyen (see note 29); Ditsuwan (see note 33).

42. Soumahoro (see note 14).

43. Ibid; J. Beauté and S. Vong, "Cost and disease burden of dengue in Cambodia," *BMC Public Health* 10 (2010), p. 521.

44. S. S. Patil, S. R. Patil, P. M. Durgawale et al. "A study of the outbreak of Chikungunya fever," *Journal of Clinical and Diagnostic Research* 7/6 (2013), pp. 1059–62; S. Aswathy, S. Dinesh, B. Kurien, et al. "A post-epidemic study on awareness of vector habits of Chikungunya and vector indices in a rural area of Kerala," *The Journal of Communicable Diseases* 43/3 (2011), p. 209–215.

45. Krishnamoorthy (see note 14).

46. Ibid.

47. Seyler (see note 14).

48. D. V. Clark, M. P. Mammen, A. Nisalak et al. "Economic impact of dengue fever/dengue hemorrhagic fever in Thailand at the family and population levels," *The American Journal of Tropical Medicine and Hygiene* 72/6 (2005), p. 786–791; Beauté (see note 43).

49.UN Committee on Economic, Social and Cultural Rights (CESCR), General Comment No. 14, The Right to the Highest Attainable Standard of Health, UN Doc. No. E/C.12/2000/4 (2000).

50.Ibid.