Vector-borne diseases and global warming: are both on an upward swing?

Scientists are still debating whether global warming will lead to a further spread of mosquitoes and the diseases they transmit

The effects of global warming have long been a focus of scientists' attention, not only since the USA rejected the Kyoto Protocol, which was drafted to curb the emission of so-called greenhouse gases. The potential consequences of increasing the Earth's temperature by just a few degrees include a rise in ocean levels due to melting of the polar ice caps, parching of the land and changes of storm, flood and drought patterns. These scenarios are mainly debated among climatologists, but biologists are adding a further dimension with another potentially disastrous effect.

'In the past five years, there has been increasing discussion about global warming and its potential impact on diseases like malaria and dengue fever in the tropics and even in temperate zones', Uriel Kitron, Professor of Epidemiology at the University of Illinois in Urbana-Champaign, said. Indeed, many scientists point to global warming as a factor in the spread of malaria and other vector-borne infectious diseases. This camp believes that global warming is likely to disturb a delicate equilibrium and contribute to new epidemics of malaria, yellow and dengue fever and encephalitis.

Kitron has been studying the invasion of

eases. 'Vector-borne diseases have an extremely complex ecology, which renders transmission and what it takes to produce disease not that simple and clear cut', he said.

Unlike Kitron's middle-of-the-road view, much of the scientific thinking on the topic is polarised, and seems to be tinged with politics. Paul Epstein, Associate Director of the Center for Health and the Global Environment at Harvard University noted in *Scientific American* that undesirable effects such as mosquito-borne disorders are likely to occur. 'Anopheles mosquitoes [...] cause sustained outbreaks of malaria only where temperatures routinely exceed 15.5°C. Similarly, *Aedes aegypti* mosquitoes, responsible for yellow fever and dengue fever, convey virus only where temperatures rarely fall below 10°C', Epstein writes. 'While excessive heat kills insects as well as cold, within their survivable range of temperatures, mosquitoes proliferate faster and bite more as the air becomes warmer.' He points out that heat promotes pathogen development: at 20°C, immature *Plasmodium falciparum* takes 26 days to mature, whereas at 25°C, it takes only 13 days.

and New York as well as in Toronto', Epstein writes. He points out that malaria has made a comeback in Korea, parts of southern Europe and the former Soviet Union and the South African coast, while dengue fever has also been spreading to the Americas and northern Australia in the past decade. While he acknowledges that these outbreaks could also be connected with a decline in mosquito control, he sees global warming as the most likely source for the current spread of vector-borne diseases.

Strongly critical of Epstein's hypothesis is Andrew Spielman, Professor of Tropical Public Health in the Department of Immunology and Infectious Diseases at the Harvard School of Public Health. 'The proponents of climate change's impact on these diseases have not substantiated their claims with facts', said Spielman, who believes that social conditions have more impact on the spread of vector-borne diseases than climate. Epstein's work 'stimulates conversation' but grossly oversimplifies the issue and jumps to the wrong conclusion, he criticised.

Nevertheless, more recent studies seem to support Epstein's warning. Jonathan Patz of the Johns Hopkins School of Hygiene and Public Health in Baltimore, MD, and co-author William Reisen reported in April in *Trends in Immunology* that changes in the African highlands' temperatures—a rise of 1.5 to 6°C by 2100—could enhance malaria transmission in sub-Saharan Africa, where over 90 percent of the world's 300–500 million cases occur annually. 'In the cool highlands, where temperatures frequently fall below the threshold for parasite development in the mosquito host, small increases in temperature can disproportionately

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the tiger mosquito in Illinois, LaCrosse encephalitis in the Great Lakes region, and dengue and malaria in Trinidad, Kenya and Mozambique. His research, however, does not clearly link global warming with the spread of these dis-

Furthermore, mosquitoes could expand into new territories. 'Since 1990 [...] when the hottest decade on record began, outbreaks of locally transmitted malaria have occurred during hot spells in Texas, Florida, Georgia, Michigan, New Jersey

enhance malaria transmission,' they write. 'In these highland and Sahel fringe areas, resident populations have little or no immunity, and epidemics during favourable climactic conditions can be devastating, affecting adults and children alike.' The minimum temperature for the development of *P. falciparum* and *P. vivax* in the mosquito host is about 18°C and 15°C, respectively, and these thresholds delimit malaria at higher elevations. But malaria outbreaks have been reported at altitudes of 2000 m in western Kenya when mean monthly temperatures exceeded 18°C and rainfall exceeded 15 cm per month. Patz and Reisen also note that warming trends in the American southwest could endanger non-immune elderly persons who spend the winter there.

Rising temperatures could also extend the transmission season for the dengue

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Warming trends in the American southwest could endanger non-immune elderly persons who spend the winter there

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haemorrhagic fever/dengue shock viruses and increase the rate of their development within the vector, thus producing more infectious bites per year, they add. Droughts could encourage the storage of drinking water, thus increasing the number of development sites of its vector, the *A. aegypti* mosquito, while high rainfall could expand mosquito populations by producing new breeding grounds.

The increase of infectious diseases due to global warming was also a topic at the Cleveland Vector Encounter in July, where 60 researchers from the US and Canada gathered at Case Western Reserve University. Barry Alto of the University of Florida in Gainesville discussed the dynamics of temperature on *Aedes albopictus*, the Asian tiger mosquito. His paper, published in July in the *Journal of Medical Entomology*, examined how constant temperatures of 22, 24 and 26°C affect the full life-cycle of caged mosquitoes. Alto found that populations at higher temperatures increased faster and had shorter development times. 'The study suggests that regional differences in temperature are likely to affect the ability of species—most notably that of the Asian tiger mosquito—to colonise new areas', Alto said.

He concluded that higher temperatures associated with climate change—when considered alone—'seem likely to expand the region of North America that is suitable for *A. albopictus*. Warmer winter temperatures should reduce winter mortality. Warmer summer temperatures should favour earlier, more rapid production of adults, and yield an increase in the rate of spread of *A. albopictus* to new sites.'

In another study, published in the August issue of *Journal of Medical Entomology*, Patz and co-author Steven Juliano examined rainfall and temperature effects on *A. albopictus*. Specifically, they found that greater temperatures and the absence of drying resulted in larger production of adult mosquitoes while greater temperatures with drying diminished populations. 'These results suggest that populations occurring in warmer regions are likely to produce more adults as long as containers [mosquito-breeding grounds] do not dry completely', Alto said. He concluded that 'predicted climate change in North America is likely to extend the northern distribution of *A. albopictus* and to limit further its establishment in arid regions'. These conclusions may also pertain to dengue, LaCrosse encephalitis and Venezuelan equine encephalitis, which have been spreading through the Americas, Alto said. Of course, such problems would not be limited to the Americas, but would also pertain to other areas with higher temperatures and sufficient rainfall, such as southern Europe or northern Australia.

But there are many factors to take into account. 'I believe that with global warming, patterns of disease could change, but how that will occur is unclear', Kitron

supports Kitron, noting that the life-cycle and distribution of vectors and infectious diseases are far more complex than others acknowledge. Reiter cited numerous cases of historical malaria epidemics during record cold temperatures in specific regions, such as the first major epidemic of dengue in 1780s in Philadelphia where *A. aegypti* survived the winters in basements where water was stored, malaria epidemics in Russia and Finland in 1939–40, and in Poland through the 1950s. 'There is tremendous distribution of vector-borne diseases in temperate regions, and this has always been the case', he said. 'It is unfortunate that public perception is distorted by people who know little about the field'. This line of thinking is 'politically sexy' but reductionist, he said.

In April 2001, an interdisciplinary committee of the National Academy of Sciences' National Research Council (NRC) published a report arguing that there is 'little solid scientific evidence' to support warnings that climate change will promote an upsurge of dengue, malaria and yellow fever. The report noted that a number of the studies used to support the correlation of vector-borne diseases with global warming were short-term in focus, and covered relatively small areas of territory. Furthermore, models based on such studies do not consider other factors, such as sanitation, land use, public health practices, and other behaviour. One example the report gave is the incidence of dengue fever on either side of the US–Mexican border. In the 16 years after 1980, there were over 50 000 confirmed cases of dengue in the three Mexican states bordering the Rio Grande. During the same time period, there were fewer

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Public health differences—not climate—account for the large discrepancy of cases of dengue fever along the border between Texas and Mexico

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cautioned. Global warming could create a mixture of conditions that is as yet unknown; for example, less moisture or rainfall and higher temperatures could undo the effects of warming, he added. He also pointed out that social causes are at least as important risk factors as rising temperatures. Paul Reiter of the Centers of Disease Control (CDC) in Atlanta, GA,

than 100 cases on the Texas side. Public health differences—not climate—account for this discrepancy; screens on windows, air-conditioning and fewer hours spent at home result in a lower incidence of mosquito bites in Texas.

Similarly, the CDC acknowledged that 'changes in regional climate patterns caused by long-term global warming

could affect the potential geographic range of many infectious diseases', but adds, 'if the climate of some regions

borne disease is simply too complex for scientists to be able to make accurate predictions. 'The potential exists for scientists

not, the fact that biologists are also seeing potentially detrimental effects from rising global temperatures is worrisome enough. It should render additional arguments to the supporters of the Kyoto Protocol, who see it as a necessary first step to curb global warming.

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'The potential exists for scientists one day to be able to predict the impact of global climate change on disease, but that day is not here'

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becomes more suitable for transmission of disease agents, human behavioural adaptations and public health interventions could mitigate many adverse impacts'.

However different the interpretations might be, at least all scientists involved agree that the interaction between climate, human behaviour and vector-

one day to be able to predict the impact of global climate change on disease, but that day is not here', Donald Burke, Professor of International Health and Epidemiology at Johns Hopkins School of Public Health in Baltimore, MD, and chair of the NRC panel, remarked. Nevertheless, whether the threat of vector-borne diseases spreading into new areas is realised or

Killing the right bug

Phenotypic and genotypic approaches for identifying infectious agents and antibiotic resistance can help to slow the increasing antibiotic resistance among infectious bacteria

When antibiotics became available after World War II, they were little short of a miracle. Since then, their ability to fight bacterial infections quickly and effectively has literally saved the lives of millions around the globe. But their effi-

ciency has also been their greatest weakness, as people now rely on antibiotics to fight any infection whether it makes sense to use them or not. Added to which, most clinicians and physicians, under pressure to save time and money, will prescribe a broad-spectrum one-size-fits-all antibiotic to any patient with a bacterial infection rather than choosing a narrow-spectrum antibiotic targeted to the specific causative pathogen. In the case of life-threatening infections this is certainly justified. But this over-use of antibiotics in hospitals and private practices has inevitably selected for resistant bacteria that are increasingly able to withstand the very drugs designed to combat them. Public

health experts therefore urge clinicians and physicians to prescribe more narrow-spectrum antibiotics in order to slow the spread of resistance among bacterial strains. But to do so, clinicians must know as soon as possible which bug they are

bacterial populations provide a perfect breeding ground for multi-resistant super-bugs. Worldwide deaths from methicillin- and the emerging vancomycin-resistant *Staphylococcus aureus* (MRSA and VRSA, respectively) amount to 5000 each year. Previously benign organisms such as *Enterococcus faecalis*, *Acinetobacter* and *Xanthomonas* can now be fatal to hospitalised patients with compromised immunity. But also in the community, *Streptococcus pneumoniae* and *Neisseria gonorrhoeae* that were once easily treatable with penicillin, are now resistant to most common antibiotics. An analysis of non-hospital antibiotic sales in the 15 European Union member states (Table I), published last June in *The Lancet* by Otto Cars and co-workers from the Department

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dealing with and to which antibiotic the strain is susceptible, and this can take up to weeks using traditional culture-based methods. Some automated systems are available to determine the infectious strain and its susceptibility to antibiotics within hours, but they come with a price. In the long run, therefore, they will most likely be replaced by DNA-based solutions that will cost a fraction of traditional methods and will be able to identify an infectious agent and its resistance in less than an hour.

The problem of emerging resistance is greatest in hospital environments where the high level of antibiotic use and the propensity for genetic exchange between

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There is a prevailing attitude which borders on a sense of complacency that science will provide the answer

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of Infectious Diseases at the University Hospital in Uppsala, Sweden, highlights the problem of over-prescribing. In 1997, France and Spain were the highest