Under the Sun **Human Ecology**

Climate change and global infectious disease threats

Erwin K Jackson

The world's climate is warming up and, while debate continues about how much change we can expect, it is becoming clear that even small changes in climate can have major effects on the spread of disease. Erwin K Jackson, a member of Greenpeace International's Climate Impacts Unit and a delegate to the 11th session of the United Nations Intergovernmental Panel on Climate Change (Rome, 11–15 December), reviews the scientific evidence of this new global threat to health.

"It is ... disturbing to note the apparent lack of interest in global warming as a possible contributor to public health crises ...", noted the US Institute of Medicine's Committee on Emerging Microbial Threats to Health in 1992.[1] Today, there is a growing scientific concern that the long term impacts of climate change may represent the greatest environmental health risk to face humanity.[2-4]

A consensus is emerging on what are the potential direct and indirect implications of climate change for human health,[3,5] despite complexity surrounding its accurate assessment.[6] Direct impacts involve the loss of life and sickness from the increased frequency, severity and geographic extent of extreme climate events, such as heatwaves and floods. Indirect impacts include changes in food supply due to the disruption of agriculture and fisheries, the spread of infectious diseases, and the climate-enforced mass migration of people.

Human-induced climate change

Some gases allow incoming solar radiation to pass through the atmosphere but trap outgoing longwave radiation close to the Earth's surface. This process is known as the "greenhouse effect". Without it, the planet's surface temperature would be 33°C lower than it is today and life as we know it would not exist.[7]

Since the Industrial Revolution, human activities have increased the atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and several other important greenhouse gases, leading to an enhanced greenhouse effect.[7-9] Carbon dioxide is the most important anthropogenic greenhouse gas, and atmospheric concentrations of CO_2 have increased by nearly 30% due to the combustion of fossil fuels, cement production and deforestation. This human-enhanced greenhouse effect has been tempered to some extent by the action of aerosol particles, also emitted by human activity.[9]

In 1988, the United Nations formed the Intergovernmental Panel on Climate Change (IPCC) to assess the threat of human-induced climate change. The assessments of the IPCC now represent the work of more than 2500 scientists and are considered the pre-eminent opinion and scientific consensus on climate change. In 1990 the IPCC concluded: "We are certain ... [greenhouse gas] increases will enhance the greenhouse effect, resulting on average in an additional warming of the Earth's surface."[7]

Global average temperatures have risen by 0.3–0.6°C since the late 19th century (Table 1). In both their 1990 and 1992 reports, the IPCC concluded that, while this increase was consistent with projected climate change, it would be a decade or more before they could rule out the natural variability of the climate system.[7,8] Since then, however, scientific opinion has shifted.[10] Observed changes increasingly match climate simulations that include aerosols. While this does not constitute proof, a growing number of reports now suggest that observed changes in global temperature are not caused by the natural variability of the climate system, and conditionally point to the combined effect of increased atmospheric concentrations of greenhouse gases and aerosols.[11-14]

Climate change and emerging infectious diseases

The current diversity of infectious disease threats facing humanity is unprecedented.[15] The last two decades have seen a resurgence of malaria, dengue, cholera and tuberculosis, while human immunodeficiency virus (HIV), viral haemorrhagic fevers and hantavirus pulmonary syndrome have appeared unexpectedly in new populations.[1,15,16] William Forge, the former director of the US Centers for Disease Control and Prevention (CDC), coined the term "global infectious disease threats" because international interdependence, modern transportation, trade and changing social patterns ensure that emerging infections are a global threat from which no country is sufficiently remote or disconnected to assume that its people are safe.[17]

The recent emergence of a new morbillivirus (which killed two horse trainers) in Queensland,[18] the increasing geographic

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spread of Barmah Forest virus,[19] the emergence of a lethal frog iridovirus in southeast Queensland,[20] and the first reported case of Japanese encephalitis in Australian territory[21] demonstrate that Australia can fall prey to emerging indigenous or foreign microbes.

The IPCC human health author group[3] and others[1,15,22-24] have forewarned that global climate change will exacerbate and accelerate the tempo of contemporary infectious disease emergence, particularly for those diseases transmitted by an intermediate host, or vector.

Researchers have long appreciated the role climate plays in vector-borne disease distribution,[25] and the combined effects of the projected increases in temperature and rainfall (Table 1) suggest an expansion of favourable habitats for many vector-borne diseases, regional changes from seasonal to perennial transmission (or vice versa), and the migration of vectors into areas currently disease-free, such as to higher altitudes.[3,5]

Modelling studies of climates suitable for vector-borne diseases under enhanced greenhouse conditions suggest a significant increase in the areas suitable for vector-borne disease transmission (Figure).[26-30] High risk analysis by Martens et al. suggests that an additional 620 million people could be at risk from malaria in developing countries by 2050.[30] By 2100, the number could grow to around one billion.

Climate change scenarios for Australia[31] (Table 2) suggest conditions that would significantly increase arbovirus activity (including Ross River virus and Barmah Forest virus) and Murray Valley encephalitis virus activity.[27,32-34] Vectors for dengue, yellow fever and malaria already exist in Australia; pessimistic scenarios suggest the (re)establishment of these diseases as climate change increases the favourableness of vector environments and increasing numbers of viraemic human travellers enter the country. Irrespective of whether this occurs, climate change is likely to favour localised epidemics of imported diseases.[35] Under future climate conditions, the heavily populated south-eastern regions of the country may be at risk.[27]

Humanity's ability to adapt via changes in culture, technology, migration and personal behaviour could, at least in developed countries, mitigate the impacts of climate change.[3] The elimination of malaria from Australia, for example, was a direct result of proactive public health action. Factors related to climate change and other changing circumstances will influence Australia's vulnerability to emerging infections, including:

- Demographic changes, such as an ageing population, escalating migration to coastal tropical areas and increased drug dependence and chronic illness.[36]
- The introduction of microbes and vectors by unprecedented and escalating transboundary movements of people.[37,38]
- Expanding prevalence of

Table 1: Observed and projected global climate change[7,8]

	Observed climate change		Projected climate change
	Combined land and sea surface temperatures		
❖❖❖❖❖	0.3–0.6°C global increase since 1880	❖❖❖❖❖	Surface and lower atmosphere warms
		❖❖❖❖	global average response to doubled CO_2 concentrations a rise of 1.5–4.5°C; "best guess" an increase of 2.5°C
❖❖❖❖	Diurnal temperature range decreased	❖❖❖	Diurnal temperature range will decrease
❖❖❖❖	Greatest warming over mid-latitude northern hemisphere continents	❖❖❖	Greatest warming will occur at northern hemisphere high latitudes
	Stratospheric temperatures		
❖❖❖	Stratosphere cooled since 1970s	❖❖❖❖❖	Stratosphere cools
	Ice and snow cover		
❖❖❖❖❖	Major glaciers are in retreat globally. Northern hemisphere spring snow cover decreased between 1973–1994	❖❖❖❖	Area of sea ice and snow cover will diminish
❖❖	Reduced sea ice in Arctic and around Antarctica since late 1970s		
	Precipitation		
❖❖❖	Little or no change in global average rainfall	❖❖❖❖	Global average increase
❖❖❖	Increase in high and mid-latitudes since 1900	❖❖❖	Increase in high latitudes and in mid-latitudes in winter
❖❖❖	Decrease in tropics and northern hemisphere subtropics since 1970	❖❖	Increased tropical variability
❖❖	Increase in tropical water vapour, evaporation and hydrological cycle	❖❖❖	Increase in tropical water vapour, evaporation and hydrological cycle
❖❖❖	Increase in heavy rainfall in United States, parts of Australia, Japan. No apparent change in China, former Soviet Union.	❖❖❖	Increase in heavy rainfall
	Shifts in atmospheric and oceanic circulation		
❖❖❖	Bias towards warm (El Niño) ENSO events since 1976	❖	Mean state of Pacific El Niño-like; no or little change in variability; increase in severity of associated extremes
❖❖	Decreased convection in the North Atlantic	❖❖❖	Decrease in North Atlantic ocean circulation

The principal tools for the projection of global climate change, producing advanced computer simulations of the global climate, are called General Circulation Models (GCMs). These models take into account the most important events that govern the climate system and can reproduce the main large-scale features of the global climate, including recent global warming. ENSO = El Niño and southern oscillation.
❖ reflects certainty of statement: ❖❖❖❖❖ virtually certain; ❖❖❖❖ very probable; ❖❖❖ probable; ❖❖ uncertain; ❖ very uncertain

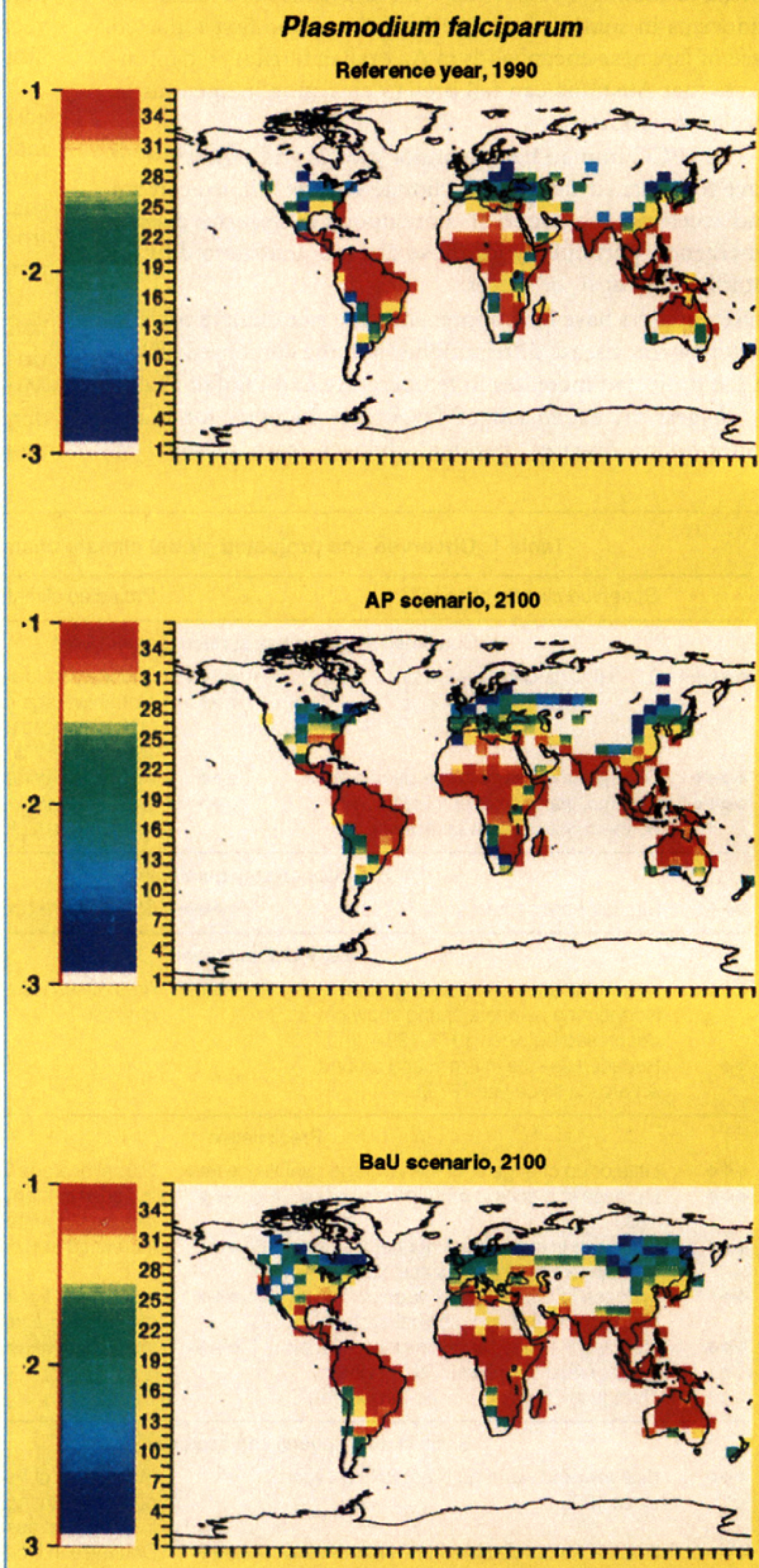
drug-resistant pathogens and pesticide-resistant vectors.[1,15]

- ◆ A potentially uncontrollable influx of millions of refugees from South-East Asia and the Pacific, displaced by climate change and rises in sea level.[39,40] These refugees would at best strain health systems or at worst overwhelm them, spreading diseases into populations with no specific immunity.[5]

The climate and ecosystems interact in a non-linear fashion, and projected climate changes lie outside human experience. There is therefore considerable scope for "surprises" in the future.[41] For example, pathogens go undetected around us and, as in the climate-related emergence of hantavirus pulmonary syndrome in the southwest United States in 1993,[17,24] could emerge as environmental change favours animal vectors.[42] As animals and humans attempt to migrate in response to climatic changes, new species will be exposed to new arthropod vectors and currently "silent" wildlife transmission cycles.[3] Disease carriers may begin to mix and, for some viruses, this "ecological overlap" would favour gene swapping between pathogens and the emergence of novel strains.[22]

A change in the distribution of infective agents and their carriers may be among the first biological indicators of climate change.[43] Recent disease emergence, attributed or partially attributed to climatic factors, suggests that such indicators may be beginning to appear:

- ◆ In the North West Frontier Province of Pakistan, a regional increase in annual mean temperature of 0.5°C since 1978 has contributed to the increase in malaria (*Plasmodium falciparum*) cases from a few hundred in the early 1980s to 25 000 in 1990.[44] An extended season of malaria and dengue activity has also been observed in Argentina.[45]
- ◆ Epidemic malaria has occurred at high altitudes over the last decade in Rwanda,[46] Zambia, Swaziland, Ethiopia, and Madagascar.[47-49] Increased temperatures and/or rainfall have acted alone or in concert with increased drug resistance to promote these epidemics. One epidemic in highland Madagascar in 1988 killed more than 100 000 people.
- ◆ Dengue has appeared at higher altitudes than previously reported in Costa Rica (at 1250 m), and in Colombia and India (at 2200 m) (Dr Paul Epstein, New and Resurgent Diseases Group, Harvard Medical School, personal communication). The previous range was limited by temperature to about 1000 m above sea level. In Mexico, the dengue vector (*Aëdes aegypti*) has been detected at 1600 m; transmission of dengue was unknown above 1200 m before 1986.[50]
- ◆ Other examples of climate-related changes in the prevalence or distribution of pathogens and their vectors include the resurgence of Mediterranean spotted fever in Spain and Italy,[51] the recent epizootic of African horse sickness in Iberia,[52] the



Potential malaria risk areas in 1990 and 2100 for Plasmodium falciparum, *expressed as the logarithm of the epidemic potential [-¹⁰log(EP)]. Based on the (equilibrium) climate patterns generated by the UK Meteorological Office GCM with the accelerated greenhouse gas reduction policies (AP) and business-as-usual (BaU) greenhouse gas emission scenarios. Figure prepared by Dr Pim Martens, Dutch National Institute of Health and Environment Protection.*

resurgence of plague in parts of southern Africa,[53] increased incidence and geographic spread of algal blooms,[54,55] outbreaks of opportunistic infections among seals,[56] and the spread and establishment of pathogens and vectors in Switzerland.[57]

Recent changes in climate throughout Australia are not inconsistent with projections of climate change (Table 2).[58] In response to successive mild winters and heavy rains, the buffalo fly (*Haematobia irritans exigua*) has spread southwards into northern New South Wales from central Queensland,[59] and in recent years relatively large climate-related arbovirus epidemics have occurred.[40,60-64] In South Australia, high rainfall and temperatures between August 1992 and February 1993 led to the proliferation of Ross River virus vectors and a subsequent epidemic of the disease. More than 800 cases were reported, compared to the average annual number of cases of fewer than 10. Smaller outbreaks occurred in 1984 and 1989 (136 and 155 cases, respectively).[40]

Table 2: Observed and projected climate change over Australia[31,58]

Observed climate change	Projected climate change (2030)
Surface temperatures	
0.4–0.8°C average annual increase since 1950	Inland: 0.5–2.5°C increase
East coast: 0.1–1.0°C average annual increase since 1910	Northern coasts: 0–1.5°C increase
Southwest Australia: 0.8°C average annual increase since 1910	Southern coasts: 0.5–2.0°C increase
Precipitation*	
Increased summer rainfall over Northern and Eastern Australia	0–20% increase in summer† rainfall‡
Decreased winter rainfall over Southwest Australia	Southern inland: 0–10% decrease in winter§ rainfall
	Southern Ocean and Tasmania: 10% decrease to 10% increase in winter rainfall
	Southern coasts: 0–10% increase in winter rainfall
Extreme events	
Decrease in extreme low temperatures	Decrease in extremely low temperatures (50%–100% decrease in temperatures below 0°C in Southeast)
No apparent change in extremely high temperatures	Increase in extremely high temperatures (50%–100% increase in temperatures over 35°C in Southeast)
Weak increase in extreme high (summer) rainfall over North	Increase in extreme high rainfall*‡
Increase in drought associated with El Niño since 1976	Potential increase in incidence and severity of drought*

* High level of uncertainty. ENSO (El Niño and southern oscillation) has a strong influence over this climatic factor and any change in the future will depend on how climate change and ENSO interact. † November–April.
‡ The future of tropical cyclones is highly uncertain. § May–October.

The role of health organisations

Climate change poses a unique challenge for health organisations and professionals. The associated health problems are of a global scale, transcend generations and are in some aspects irreversible.[65,66] They are further complicated by being indirect and, in some cases, delayed. Traditionally, environmental health problems have been related to direct environmental contamination. In the case of climate change, however, health problems relate more to human resource use overloading the life support systems upon which we depend — stable climate, tolerable temperature, fertile soils, protection from ultraviolet radiation, biological diversity and clean water.[65]

How should the health sector respond? The IPCC human health author group concludes: "... if health impacts of climate change are probable and serious, then the only effective long term basis for mitigation lies in primary prevention at the societal level. ... This ... would suggest some fundamental, and therefore difficult, reorientations of social, economic, and political priorities."[3] Similar conclusions were drawn by the WHO Commission on Health and Environment;[67] and the WHO Task Group on climate change concluded that: "The health sector must play an active role nationally in formulating and implementing strategies to prevent climatic change and combat its effects."[5]

Current discussions aimed at reducing greenhouse gas emissions, at both international and national levels, continue to ignore the health implications of policy decisions. Experts, including the WHO Commission on Health and Environment, have concluded that the health sector must become actively involved in discussions on environmental policy to ensure that:[67]

- governments and institutions develop an awareness of the health implications of policy decisions;
- health impacts are considered fully when decisions are made;
- greater urgency is given to preventing or limiting environmental health risks in all sectors;
- governments give higher priority to forming an international consensus on environmental, economic and health issues;
- governments give priority to strategies that target the energy sector, the main source of greenhouse gases, in order to control CO_2 emissions, focusing particularly on energy efficiency measures and the development and use of renewable energy sources; and
- governments develop strategies, such as disease surveillance, aimed at adapting to the climate change that is now

inevitable because of current and historical greenhouse gas emissions.[33,65]

Conclusions

Humans are changing the climate of the Earth. Public health reports suggest climate change as a contributing agent behind the recent emergence of infectious diseases. The importance of public health as a component of global environmental change cannot be ignored any longer. It bestows on governmental and non-governmental public health organisations a new mandate — that of making public health a central environmental policy item and assisting decision makers in designing health-conscious environmental policies.

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