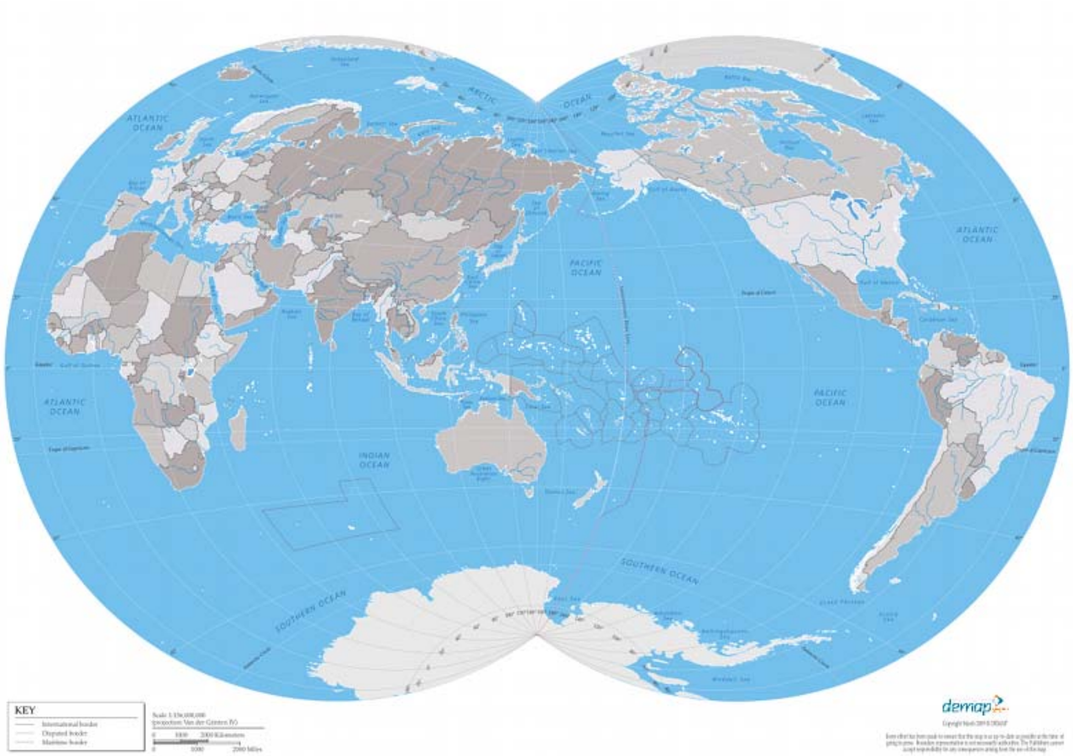
Climate Change in Australia: Risks to Human Wellbeing and Health



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Synopsis

Anthony McMichael from the Australian National University writes that "climate change belongs to a wider range of human-induced global environmental changes that are now assuming great and urgent importance. Collectively, these changes signify that human pressures are weakening and endangering the planet's life-support systems. Climate change will have many, and diverse, effects on human biological processes, risks of injury, and hence on health." McMichael discusses the adverse health impacts of climate change on those most likely to bear the greatest burden: low-income, poorly-resourced and geographically vulnerable populations. "The range of adaptive strategies is very wide, with options at all levels from national through to household and individual levels", McMichael argues. "They include, for example, early-warning systems for heat-waves, community alerts for fragile older persons, better surveillance systems for the detection of shifts in infectious disease patterns, strengthened physical barriers against weather disasters, enhanced disaster response preparedness, and food supplementation systems." McMichael concludes that "some adaptive strategies will be needed at supranational level. This includes the need for regional early-warning of intensified storms and cyclones, for transboundary flooding via amplified river flows, and for the anticipated spread of climate-sensitive infectious diseases. Within this frame, there will be a number of needs and opportunities for cooperative arrangements and for information-sharing between neighbouring countries – as in the case of Indonesia and Australia."

About the Author

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Introduction

This paper focuses on the current and future impacts of human-induced climate change on human health, with particular reference to Australia. The possible overlaps and interactions with Indonesia are also addressed, including the in-principle possibilities of shared adaptive responses.

Before conducting a detailed assessment, it is crucial to recognise the full nature of the problem. Otherwise we risk continued procrastination and inadequate response in relation to mitigation.

Climate change is becoming understood as a more profound problem than we imagined a brief decade ago. It threatens more than iconic species and ecosystems, human-built infrastructure, our economy, and recreational amenity. If not constrained, soon, climate change poses a threat to the foundations of Earth's life processes. One clear indication of this is the well-documented impact that climate change is already having on much of the living world: plants, animals, insects and whole ecosystems have begun to undergo changes that are attributable to warming. As for all those non-human species, so do human wellbeing and health depend fundamentally on natural environmental processes and products – even though those of us who live in modern urbanised societies, where we have little direct contact with the natural world, may not recognise this profound truth.

Climate change belongs to a wider range of human-induced global environmental changes that are now assuming great and urgent importance (Table 1). Collectively, these changes signify that human pressures are weakening and endangering the planet's life-support systems. Each of those changes is a consequence of the escalating environmental pressures exerted by the ongoing increases in both human numbers and intensity of economic activity at global and regional scales [1].

Table 1. The main categories of human-induced global environmental changes

- Climate change: altered radiative forcing in the lower atmosphere (troposphere) due to elevated concentrations of greenhouse gases
- Destruction, in middle atmosphere (stratosphere), of ozone – the gas that absorbs much of the incoming biologically-damaging solar ultraviolet radiation
- Acidification (via increased CO2 uptake), and warming, of the world's oceans: a threat to the future vitality and productivity of marine fisheries
- Changes to the global cycles of several important elements, including nitrogen, sulphur, phosphorus
- Accelerating loss of biodiversity, with consequent disruption of ecosystems: habitat loss, over-harvesting, climate change, pressures from infectious agents
- Degradation and loss of much arable land: over-exploitation, erosion, urban-industrial spread
- Depletion of freshwater supplies: aquifers, river flows, wetlands loss

Just over twenty years ago, the eminent American oceanographer, Wallace Broecker [2] wrote: "The inhabitants of Earth are quietly conducting a gigantic experiment. So vast and sweeping will be the consequences that, were it brought before any reasonable council for approval, it would be firmly rejected. …. We play Russian roulette with climate, hoping that the future will hold no unpleasant surprises. No one knows what lies in the active chamber of the gun." Today, that concern looks more urgent. For example, global temperature rises of 5-plus degrees Centigrade over the next several centuries now loom as at least plausible, if not yet actually probable. The approximately 0.7^{o}C rise that has occurred over the past century has impinged very unevenly. The high Arctic region has already experienced rises of 3-4^{o}C.

While global climate change gathers momentum, many populations continue to face age-old perennial environmental hazards (water-borne infections, malnutrition, physical hazards, and, accompanying various modernization trends, the rise of non-communicable diseases). Those long-standing and familiar scourges of health are necessarily the focal points for many of the UN's eight Millennium Development Goals. Disappointingly, however, Goal 7 (reducing environmental damage and achieving environmental sustainability) is treated as an essentially separate problem [3]. Yet changes to the prevailing climatic and environmental milieu (as summarised in Table 1) will tend to exacerbate, to amplify, those more sedimentary health problems.

Climate Change and Health

Changes in the world's climatic conditions will have very many, diverse, effects on human biological processes and risks of injury, and hence on health [4]. Some health impacts will occur by direct-acting pathways, via physical injury and thermal extremes. Others will occur via climatic influences on complex ecological, biological and social systems. This includes, for example, changes in the risks of infectious disease transmission, food yields, and – via even more extended pathways – the various mental and physical health risks that typically follow social and economic disruption and dislocation (see Figure 1).

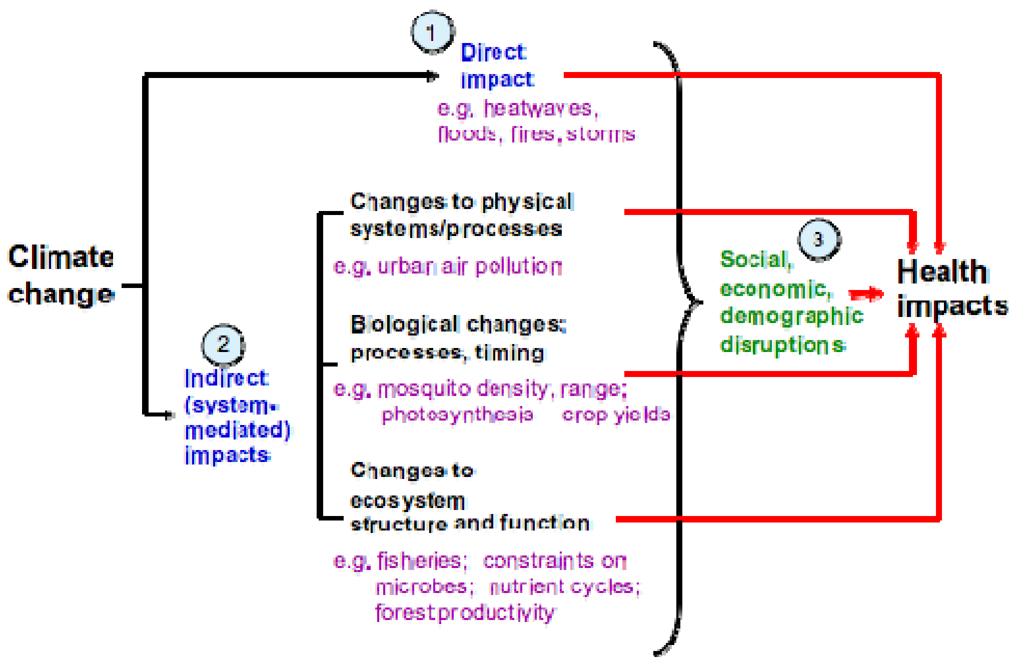

Figure 1. The three major categories of pathway via which climate change affects human health.

Many of the health impacts will be modulated by the coexistent influences of other environmental changes. A good example is the impact of climate change (along with freshwater shortage, soil erosion, and alienation of land to urbanization) on agricultural yields, food prices and, hence, on nutrition and health. In addition to that more obvious health consequence of impaired agricultural productivity – perhaps not an immediate threat to the health of most Australians – the impacts of climate change on local rural environments and food yields, and hence on community vitality and livelihoods, will also affect mental health and health-related behaviours.

Note that the crucial point underlying any description of current and likely future health impacts is that climate change will affect more than built infrastructure, environmental amenity, the economy and jobs. It will increasingly disrupt and deplete the natural systems that support and supply the processes of life. That threat is the one that embodies the greatest long-term danger posed by global climate change. Therefore, not only do we wish to avert risks to health, but the fact that such risks exist serves notice on us that global climate change is a greater danger than we originally imagined.

Over the past decade climate change research has paid increasing attention to the increased variability in weather patterns that will result. In Australia, we can expect more injuries, deaths, post-traumatic stress disorders, and infectious disease outbreaks as a result of more frequent or intense extreme events, including storms, cyclones, floods, and bushfires.

Many infectious diseases are sensitive to climatic conditions. *Salmonella* and other food-poisoning increases in hot weather; dengue fever outbreaks are favoured by rain and surface water (for mosquito breeding); various other mosquito-transmitted viral infections (such as Ross River virus) are sensitive to temperature, rainfall and tidal patterns; cryptosporidium contamination of drinking-water reservoirs is more likely with heavier rainfall and rural run-off.

These impacts will not occur evenly – and this fact imparts an important moral imperative to the urgent averting of climate change. It also underscores the important need to understand which population segments and which regions are most vulnerable in order to formulate appropriate adaptive strategies to lessen those risks to health.

In particular much of rural Australia is likely to be affected by a global trend towards mid-latitude drying, an anticipated consequence of climate change. Rural communities, families and individuals are thus likely to bear the brunt of the early stages of climate change. In many areas, those communities are encountering increasing stresses from water shortages, warmer average temperatures, and more extreme bushfires. Livelihoods are contracting in some locales, as are towns and rural community institutions. The many health risks include direct hazards of exacerbated extreme conditions (temperature, dust, smoke), threats to mental health, risks from freshwater shortage and impaired local fresh food production, and changes in health-related behaviours.

The main risks to health from climate change in Australia are listed in Table 2. Not listed are the rather fewer possible health benefits. The benefits include a reduction in cold stress during winter months in some parts of Australia, and hence a reduction in those cardiovascular and respiratory disease events that are be influenced by extremes of cold. The circulation and the transmission of several infectious diseases (e.g. rotavirus, which peaks each winter) might also be curbed by a reduction in cold conditions in winter time.

Table 2. Summary of main health risks from climate change in Australia

- Increased illness events and deaths from more frequent and severe heat-waves, especially in urban environments. Evidence from time-trends over recent decades points to an increase in the annual numbers of deaths in association with an uptrend in the annual number of very hot days. The heat-associated death rate in persons aged over 65 years, in major cities, could increase by 2-to-4-fold by the latter half of this century – and probably more if future changes in weather variability are allowed for.
- Increased injury, death and post-traumatic stress disorders from increases in other extreme weather events – esp. floods, storms, cyclones (moving further south), and more extreme bushfires.
- Increased risks of infectious food-poisoning (gastro-enteritis), from salmonella, campylobacter, various temperature-sensitive vibrios, and others.
- Changes in the range and seasonality of outbreaks of mosquito-borne infections – dengue fever in northern Australia (likely to spread south, down both eastern and western coasts), Ross River virus disease, Barmah Forest virus disease, and others.
- Fresh-water shortages in remote (especially indigenous) communities, with consequences for hygiene and sanitation.
- Regional increases in the production of various plant-derived aeroallergens (pollens, spores) that cause/exacerbate asthma.
- A potentially serious range of adverse health impacts of more severe droughts and long-term drying conditions on rural communities. These include adverse impacts on:

  Mental health (depression and suicides)
  Child emotional and developmental experiences
  Exposures to extremes of heat, dust, smoke
  Freshwater shortages and hygiene
  Local food availability
  Changes in health–related behaviors (e.g., alcohol, smoking, self-medication)

- The spectrum of risks to wellbeing and health from the anticipated increase in geopolitical instability in the Asia-Pacific region, due to climate change, and the increase in flow of environmental refugees [5]. There are substantial implications for mental health and nutritional problems (especially in environmental refugees), infectious disease risks, and conflict situations.

The final dot point in Table 2 refers to a potentially very important regional risk to human wellbeing, health and physical safety. Climate change, combined with population growth and other environmental change, will place serious stresses on many countries. Within the Asia/Pacific region it is therefore likely to exacerbate poverty, diminish food supplies and food access, increase out-migration, and may lead to large scale population displacement. Many of Australia's neighbouring nations – in both the Pacific and parts of Asia – are very susceptible to various of the adverse impacts of climate change. This includes, of course, the many small island states in the Pacific Ocean (and some in the Indian Ocean) exposed to sea-level rise. The most vulnerable of these island populations are already beginning to experience disruption and some political agitation, and the beginnings of out-migration.

The timing and geographic pattern of population displacements will depend very much on the quality of governance and other social and cultural factors which contribute to social and ecological resilience. Even in the most optimistic of plausible scenarios, the number of displaced people within the Asia-Pacific region is likely to greatly increase this century. This will have ramifications both for regional population health and also for regional foreign policy. While substantial uncertainty exists in relation to this prediction, the geographical scale, large population size and complex variety among the peoples of the Asia-Pacific region are so vast that it is implausible that all socio-ecological units will cope well with these forecast stresses. Some countries, such as Cambodia, Papua New Guinea, and small island states appear particularly vulnerable.

A recent assessment, by Australian researchers, of this issue of geopolitical instability concluded that, as environmental and demographic stresses (and hence social and economic stresses) increase, there is likely to be a shift towards authoritarian governments [6]. In the extreme, large-scale state failure and major conflict could generate hundreds of millions of displaced people in the Asia-Pacific region, a widespread collapse of law, and serious abuses of human rights.

Projected main, IPCC-assessed, climate change impacts on health in the Asian region

The IPCC, in its Summary for Policy Makers of the conclusions in the Fourth Assessment Report (2007) projected that crop yields could increase up to 20% in East and South-East Asia, while they could decrease by up to 30% in Central and South Asia by around 2050. This assessment, taken alongside the influence of rapid population growth and urbanisation, the risk of hunger and under-nutrition is projected to remain very high in several developing countries in this region.

The other major risk to human health in this region is in relation to diarrhoeal disease and, in particular, cholera. Endemic morbidity and mortality due to diarrhoeal disease are expected to rise in East, South and South-East Asia primarily because of increases in floods and droughts due to projected changes in the hydrological cycle associated with global warming. The scientific evidence also indicates that increases in coastal water temperature would exacerbate the abundance and/or toxicity of cholera in South Asia.

Estimating current and future burdens of disease due to climate change

The recent Garnaut Review of climate change impacts in Australia, conducted during 2007-08, included the modelling of selected future health risks in Australia in relation to a set of climate change scenarios that extended out to 2100, generated by CSIRO (http://garnautreview.org.au). The quantitative component of the assessment comprised three main categories of discrete health outcomes:

1. Temperature-related mortality and hospitalisations;
2. *Salmonella* and other non-viral gastroenteritis; and

3. Dengue fever (a mosquito-borne viral infection, for which the likely changes to the geographic range and size of the population at risk can be estimated).

These three outcomes were chosen because, first, they have a previously well-demonstrated association with climate and, second, there existed both relevant Australian data and an understanding of causal mechanisms. In the case of *Salmonella* and dengue the 'base-line' climate-disease relationship over recent decades had been estimated in prior studies, while the corresponding base-line relationships for mortality and hospitalisations due to short-term variations in temperature were calculable as part of this particular review process. Hence, for all three health outcomes it was possible to apply existing or readily determined climate-health relationships to the prescribed scenarios of future climate change in Australia.

An assessment coordinated by the World Health Organization earlier this decade used a similarly selective approach to estimating the burden of disease, globally and by major region, attributable to the climate change that had occurred by year 2000 relative to the average climate during 1961-1990 [7]. That analysis was restricted to health impacts for which there was a satisfactory quantitative basis, from prior published research. The list comprised malaria, diarrhoeal disease, malnutrition, the impacts of flooding, and, in OECD countries, deaths due to periods of very high temperature.

Extrapolation of that initial partial estimate suggests that global climate change, currently, is causing around 200,000 extra deaths each year from malnutrition, diarrhoeal disease, malaria, and floods, almost all in developing countries. National greenhouse emissions accounting indicates that Australia 'causes' around 2,500 of those deaths, in other countries, each year.

Climate, climate change and infectious disease

It is a commonplace observation that many of the world's major infections occur at higher rates in warmer seasons and in the warmer and wetter regions of the world, especially the tropical and sub-tropical countries. To an extent, the direct role that climate and weather *per se* play in these variations remains unresolved. However, evidence from basic laboratory science and epidemiology makes clear that temperature and other climatic variables can influence both the actual incidence of infectious disease and various of the mediating determinants of that incidence, including influences on the vertebrate hosts of zoonotic pathogens and on mosquitoes and other arthropod vectors.

The apparently accelerated emergence of new infectious diseases has created much interest in recent years, with zoonoses particularly prominent among these [8]. It is less clear whether climate change has yet significantly influenced changes in the incidence of previously known infectious diseases, and, therefore, uncertainties persist as to what will be the likely impacts in future.

Food- and water-borne infections

In Australia, food-poisoning (gastroenteritis) shows a well-recognised rise in incidence in the warmer months. A time-series study of Australian capital city populations has shown a clear rise in the rate of occurrence of salmonellosis with preceding monthly temperature [9]. There is some anecdotal evidence that exposure to water-borne cryptosporidium in Australia is more likely at warmer temperatures

In poorer, crowded, populations the occurrence of flooding, on top of inadequate provision of safe drinking water and sanitation, greatly increase the risks of diarrhoeal disease, including cholera. For example, a time-series study in Lima, Peru, concluded that a 1^{o}C increase in temperature led to an 8% increase in hospitalizations for paediatric diarrhoeal disease [10]. Two studies of cholera in South Asia have concluded, respectively, that climatic variables, particularly maximum temperature, predict cholera cases in Bangladesh [11], and that, historically in south-east India, the seasonal extremes of dryness and flooding each account (via different variables) for most of the occurrence of cholera outbreaks [12].

Vector-borne infections

Climate zones broadly determine the potential distribution of mosquito-borne diseases. Various local environmental, cultural, socio-economic and public-health programmatic factors determine the extent to which the disease actually occurs. For the zoonotic diseases, there are often complex intermediate ecological influences involving non-human vertebrate species. Seasonal and monthly weather conditions, too, exert a major influence on the incidence of disease.

Rainfall and temperature affect mosquito breeding and feeding activity, and temperature affects the incubation of the pathogen within the mosquito. Humidity strongly affects mosquito survival, and hence the probability of completed pathogen incubation and disease transmission [13].

Ross River virus

Ross River virus disease, caused by an *alphavirus*, is an 'Australian' mosquito-borne disease – although isolated outbreaks have occurred offshore. Currently, there is an average of around 4,300 cases reported annually. The substantial research literature on the complex relation between climatic variables and Ross River virus disease occurrence is compounded by the fact that this relationship appears to differ by geographical area.

The range of RRV appears to have expanded in Queensland in recent decades, as indicated by the increasing number of jurisdictions in which the disease has been notified [14]. Various human behaviours affect the risk of RRV transmission. This and the natural complexity of RRV ecology and epidemiology pose a challenge to determine how and to what extent climate change is the cause of changes in disease frequency.

Dengue fever: a risk shared by northern Australia and Indonesia

Dengue is the most common arbovirus infection in humans. The reported incidence and geographic range of the disease, worldwide, has increased greatly over recent decades. This includes a substantial increase in incidence during the past several years in Indonesia. Elsewhere in this region, there have been recent epidemics in Tahiti and Singapore [15], along with increasing numbers of epidemic outbreaks in North Queensland [16]. Meanwhile, local transmission of dengue now occurs in most years in northern Australia.

Humans are the main host of the virus, which is transmitted by *Aedes* mosquitoes – the most important of which is the now-predominantly urban species *Aedes aegypti*. There are four serotypes of the dengue virus. Dengue haemorrhagic fever and dengue shock syndrome are life-threatening complications that apparently result from a repeat dengue infection with a different viral serotype to that which caused the initial infection.

Dengue fever is transmitted in Australia by the freshwater breeding mosquito *Ae. aegypti*. The north and central areas of Queensland are considered potentially receptive to the establishment of dengue, although there is no evidence that the virus is yet endemic in Australia [17]. Outbreaks of dengue in northern Queensland have increased in both frequency and duration over recent years, a trend which may lead to endemicity – which, in turn, would increase the probabilities of outbreaks of dengue haemorrhagic fever [16]. Imported cases are regularly diagnosed in all capital cities. Local transmission, via mosquito, from an infected traveller occurs occasionally, and since the 1940s such secondary cases have been confined principally to the northern and eastern parts of Queensland [17]. Approximately 4,000 cases of dengue were recorded in Australia during the 15-year period 1991-2005 [18].

Dengue is sensitive to climatic conditions. Rainfall, surface water and temperature affect the mosquito range, activity and seasonality; temperature affects the rate of replication of the virus in the mosquito. Simple statistical modelling (based on a statistical model derived from the observed relation of dengue occurrence in recent years to climatic-environmental conditions) indicates that future climate change will cause the transmission zone for dengue to spread southwards on both the eastern and western coasts [6, 19].

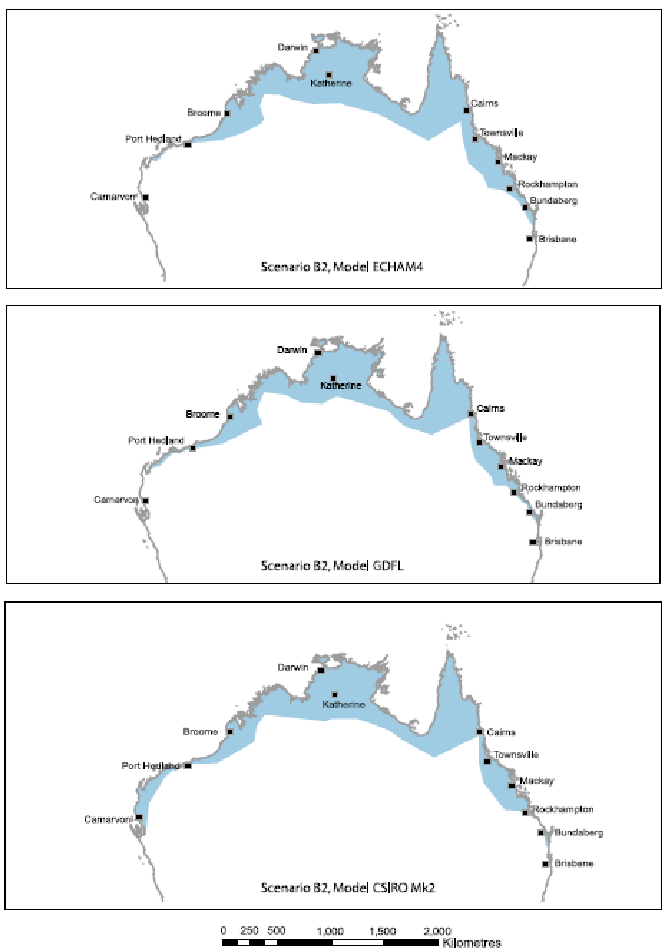

Figure 2. Estimated geographic region suitable for the transmission of dengue in 2100. Modelled with the SRES B2 greenhouse gas emission scenario applied to three different well-documented global climate models. (**From Woodruff et al 2005)**

There is, however, need for a much better understanding of the climatic and environmental determinants of dengue occurrence in Australia. This will require fieldwork in selected locations. The results should then be applied to improved modelling of how risks of transmission are likely to change over coming decades. This will provide important information for the planning of public health surveillance, mosquito control programs, public education, and rapid case detection and treatment.

Malaria

Malaria is another climate-sensitive mosquito-borne disease of concern to Australia. With the exception of a very few cases resulting from infected travellers, local transmission of malaria has not occurred since 1962.

Notwithstanding its notorious reputation and public health status internationally, malaria is easier to control than is dengue fever. The prevention of dengue requires vigilant attention to clearing or treating domestic containers that hold water and to applying mosquito repellants during outbreaks. In contrast, bed nets provide a simple and effective form of protection (since the *Anopheles* mosquito does not have the same breeding and biting habits as does the now street-wise *Ae. aegypti* mosquito that spreads dengue in Australia). For these several reasons, the risk of infection and the complexity of prevention and control are higher for dengue than for malaria in Australia.

Rural Australia: health risks

Integral to the life of rural Australian communities and families are the fluctuations and vagaries of year-to-year weather patterns. In particular, droughts occur repeatedly – although much more is known about their dynamics in relation to the El Nino Southern Oscillation (ENSO) than was the case several decades ago. The story of European settlement in Australia over past two centuries is littered with accounts of farming regions that flourished and then declined, or of disasters caused by major events, especially droughts and floods. Livelihoods are threatened, particularly in those communities that are most vulnerable, geographically or socioeconomically.

The stresses of lost income, debt and damage to property inevitably spill over into mental health problems for some, and to the tragedy of breakdown, despair and suicide for a few. The severity and distribution of these mental health problems are also influenced by aspects of community – resources, cohesion, resilience, and external supports. There is a need to understand what determines the level of vulnerability of a community or region, and how this can be modulated by community cohesion and resilience (social capital). That, in turn, will facilitate development of ‘adaptive’ coping strategies.

Previous research in Australia has indicated a positive association between drought conditions, reduced rainfall and suicide rates (especially in adult males). The disruptive and potentially demoralising effect of long-term drought conditions now poses an added risk to mental health and wellbeing. Detailed survey research will elucidate the perceptions, fears and experiences of rural people and families, how these are modulated by community support and assets, and the needs for mental health facilities.

Mental health problems account for a very substantial, though often under-recognised, burden of chronic disabling mental health disorders and of premature death – in all, or nearly all, cultures and countries. The WHO Global Burden of

Disease 2000 project estimated that, by around 2020, the burden of disease from mental health will be greater in the world than for any other major disease category. Hence, this is a high-priority research and policy topic in rural Australia.

The modelling of future climate change, along with the emerging evidence in both hemispheres, indicates that mid-latitude regions are likely to experience progressive drying [20]. This would include much of southern and eastern Australia. This drying and associated warming would, in turn, exacerbate the severity of droughts – and those may also increase in frequency in response to climate change. Australia's Bureau of Meteorology has judged that the severity of the recent drought in Australia, 2001-2007, was in part due to the underlying warmer temperatures due to climate change [21].

Vulnerability and adaptation: issues in Australia

Vulnerability, as formulated by IPCC, is a composite measure that draws on: (i) the external environmental exposure (e.g. ambient temperature), (ii) the sensitivity of the exposed group of persons (a function of, e.g., age, health status, housing conditions), and (iii) the adaptive responses already in place or at least at hand. Adaptation refers to strategies or processes that lessen the risks to health by reducing the amount of received exposure, increasing the resilience of the exposed persons, or hastening the recovery from adverse CC-caused health conditions.

Both entities, and key aspects of their relationship, are illustrated in Figure 3.

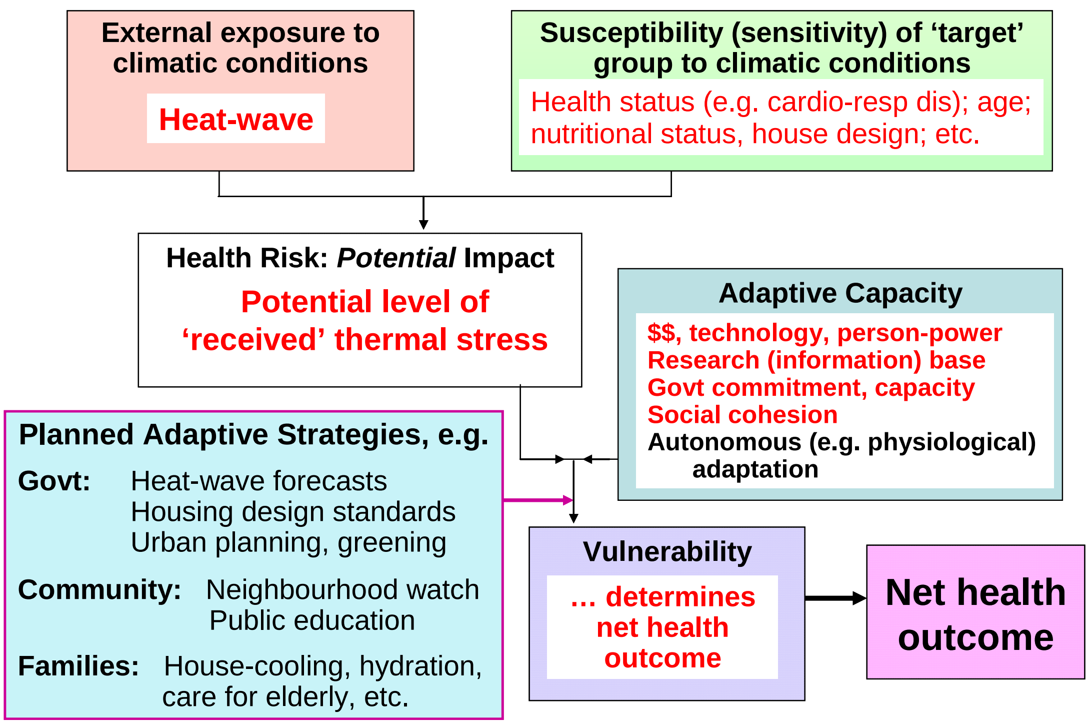

Figure 3. Determinants of vulnerability to the health risks of thermal stress. Examples are also shown at bottom-left of planned (deliberate) adaptive strategies.

Vulnerability

The most recent IPCC [22] Assessment Report emphasises that the adverse health impacts of climate change will fall primarily on low-income, poorly-resourced and geographically vulnerable populations. Many low-income countries in tropical and sub-tropical regions will be at particular risk, and especially their impoverished slum-dwelling populations. In higher-income countries differentials will also occur. In the US, for example, the impacts of the 1995 heat-wave in Chicago and the 2005 Hurricane Katrina in New Orleans differed between ethnic and socio-economic groups.

In Australia, groups likely to be vulnerable to climate change include:

- Persons living in regions where climate-sensitive infectious diseases may tend to spread
- Rural (especially farming) communities in southern and eastern Australia (exposed to long-term drying conditions)
- Older and frailer persons, especially in relation to heat-waves
- Coastal-resident communities
- Those living in current and potential cyclone risk zones
- Remote indigenous communities facing heat, drying, water shortages and loss of traditional food species

Indigenous communities face particular health risks from climate change and its environment consequences. Many indigenous communities will face extremes of heat, freshwater shortage, diminished supplies of traditional plant and animal foods, fires and other weather disasters, and erosion of parts of their cultural base. Displacement of some communities from high-risk areas (e.g. coastal sea-level rise and cyclone zones) may cause tensions and conflicts, especially if the environmental resource base is already under stress.

Adaptive responses

In principle, there is need, and social benefit, in weighting adaptive strategies towards high-vulnerability groups and sub-populations. In practice, these interventions could take many forms, depending on the scale (global, regional, local), the type of health risk, the time-frame, and the resources available. This has implications for the ways in which intervention options are selected, and the level of specificity at which they are evaluated.

The IPCC (2001) [23] noted that:

- Health impacts will be strongly influenced by local environmental conditions and socio-economic circumstances, and *by the range of social, institutional, technological, and behavioural adaptations taken to reduce the full range of threats to health*.
- Adaptation draws on “several societal systems, including access to financial resources, technical knowledge, public health infrastructure and capacity of the health-care system”.
- The recent decline in public health infrastructure in many countries could reduce capacity to prevent exacerbation of diseases and public health problems due to climate change.

The range of adaptive strategies is very wide, with options at all levels from national through to household and individual levels. They include, for example, early-warning systems for heat-waves, community alerts for fragile older persons, better surveillance systems for the detection of shifts in infectious disease patterns, strengthened physical barriers against weather disasters, enhanced disaster response preparedness, and food supplementation systems.

Some adaptive strategies will be needed at supranational level. This includes the need for regional early-warning of intensified storms and cyclones, for transboundary flooding via amplified river flows, and for the anticipated spread of climate-sensitive infectious diseases. Within this frame, there will be a number of needs and opportunities for cooperative arrangements and for information-sharing between neighbouring countries – as in the case of Indonesia and Australia.

Climate change and health: Attuning the formal public health functions

Climate change will not create qualitatively *new* human health outcomes (unless it contributes, via environmental and ecological perturbation to the emergence of some new infectious disease). Rather, climate change will alter existing exposures and conditions that pose risks to health.

The health-care and public health systems that already exist should therefore provide a foundation for dealing with health impacts of climate change. Hence, there will be a substantial reliance on incremental and complementary changes in existing health risk management strategies and resources. In generic terms these include [24].

- Modification of existing prevention strategies (e.g., introduction of new component measures, or higher settings of existing measures)
- Translation of policies and knowledge from other countries or regions to address changes in the geographic range of disease
- Reinstitution of effective surveillance, maintenance and prevention programmes that have been neglected or abandoned, and
- Development of new policies to address new threats

Basic public health functions in relation to climate change

The 10 essential functions of public health in relation to the risks posed by climate change, with examples, are as follow (adapted from a review by Frumkin and colleagues [25]):

1. Monitor the population’s health status, to identify and resolve risks to health.
    e.g. Tracking of diseases and trends related to climate change
2. Diagnose and investigate health problems and health hazards in the community.
    e.g. Assess contribution of climatic changes to outbreaks of water-, food-, and vector-borne infectious disease outbreaks
3. Inform, educate, and empower people about health issues.
    e.g. Informing the public and policymakers about health impacts and risks of climate change
4. Mobilize community partnerships and action to identify and solve health problems.
    e.g. Form public health partnerships with industry, other professional groups, community organisations and others, to develop and implement solutions
5. Develop policies and plans that support individual and community health efforts.
    e.g. Municipal heat-wave preparedness plans
6. Enforce laws and regulations that protect health and ensure safety.
    (Little role in relation to climate change)
7. Link people to needed personal health services and ensure provision of health care.

e.g. Health-care service provision following climate-related disasters

8. Ensure competent public and personal health care workforce change

e.g. Training of health care providers on health aspects of climate

9. Evaluate effectiveness, accessibility, and quality of personal and population-based health services.

e.g. Program assessment of preparedness efforts, such as heat-wave response plans

10. Research for new insights and innovative solutions to health problems.

e.g. Research on health effects of climate change, including innovative techniques such as modeling, and research on optimal adaptation strategies

The public health functions in relation to climate change and health should also include the following:

- Carry out national and (appropriate) sub-national formal health risk assessments, to identify the main health risks, their likely chronology, and vulnerable subpopulations.
- Anticipate the 'pressure points' where health impacts are most likely to appear, and ensure there is good, continuing, health-outcome surveillance in place.
- Develop methods of causal attribution, such that the public and policy-makers can be advised as to the plausible likely contribution of climate change to the impacts of otherwise 'natural' events. This also requires appropriate handling and communication of the complex issue of uncertainty.
- Develop rationally-targeted prevention (adaptive strategies). Accrue experience and understanding of the options for risk-lessening adaptive interventions. Evaluate these, for specified population sub-groups, in terms of averted disease/death/disability burden, and in terms of cost-benefit profile.
- Ensure that there is systematic updating of (future) scenario-based health risk assessments. This will assist and update the understanding by public and policy-makers of the likely future risks to health in response to specified trajectories of future social and economic change.

Conclusion

Climate change poses diverse, often serious, and growing risks to human population health. This raises, too, major issues of differential vulnerability, equity, and geopolitical destabilisation. While many impacts will be of a local kind (such as severe heatwaves or storms that affect particular cities/locations), many other impacts will be of a trans-boundary kind.

This raises important challenges for the relationship between Australia and Indonesia. Some of the trans-boundary issues and needs that relate to human health risks include:

- Monitoring/surveillance of climate-related emergence and/or spread of various infectious diseases (dengue, Japanese encephalitis, new avian viruses, etc.)
- The impacts of additional stresses on – and potential conflict over – regional fishing grounds (as an important source of protein and calories)
- The need for both countries to participate in regional alert systems – cyclones, fire-smoke, emerging food shortages, etc.
- Bilateral understanding and agreement in relation to the likely increase in ‘climate migrants’ (or ‘environmental refugees’) in the SE Asian region over coming

decades, and the handling of the health risks that they incur – and perhaps induce/transmit.

- Enhanced systems and resources for the sharing of relevant data-bases
- Opportunities and needs for sharing of expertise in this topic area, and for joint capacity-building activities

The 'silver lining' to the climate change 'cloud' may be the new and rapidly increasing pressure that climate change puts on nation-states to eschew futile go-it-alone policies, and to move towards creating a regional and world community that embraces a more cooperative, less competitive (and combative), approach to addressing tensions and problems. To survive, sustainably and comfortably, we have no other choice.

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