Climate change and health:
An exploration of challenges for public health in Victoria

A Victorian Government initiative

Victoria
The Place To Be

Climate change and health:
An exploration of challenges for public health in Victoria

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Cover illustrations

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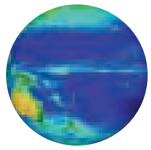
   

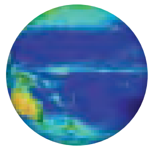
Foreword

This document was developed for the Environmental Health Unit in the Public Health Branch of the Department of Human Services, Victoria. It aims to reflect from the current literature a brief overview of the potential health impacts of climate change, and to relate this to Australia, and where possible, Victoria, providing local examples.

It does not purport to be a definitive academic treatise, but rather a baseline discussion document to stimulate interest and debate across government, non-government agencies and community groups. It is envisaged that further research and stakeholder consultation will build upon this paper as part of a risk and health impact assessment process. The Victorian Government recognises the huge challenge posed by climate change and that the time to act is now.

DR CW BROOK
Executive Director
Rural and Regional Health and Aged Care Services



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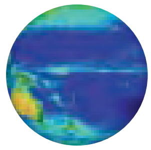


1. Introduction

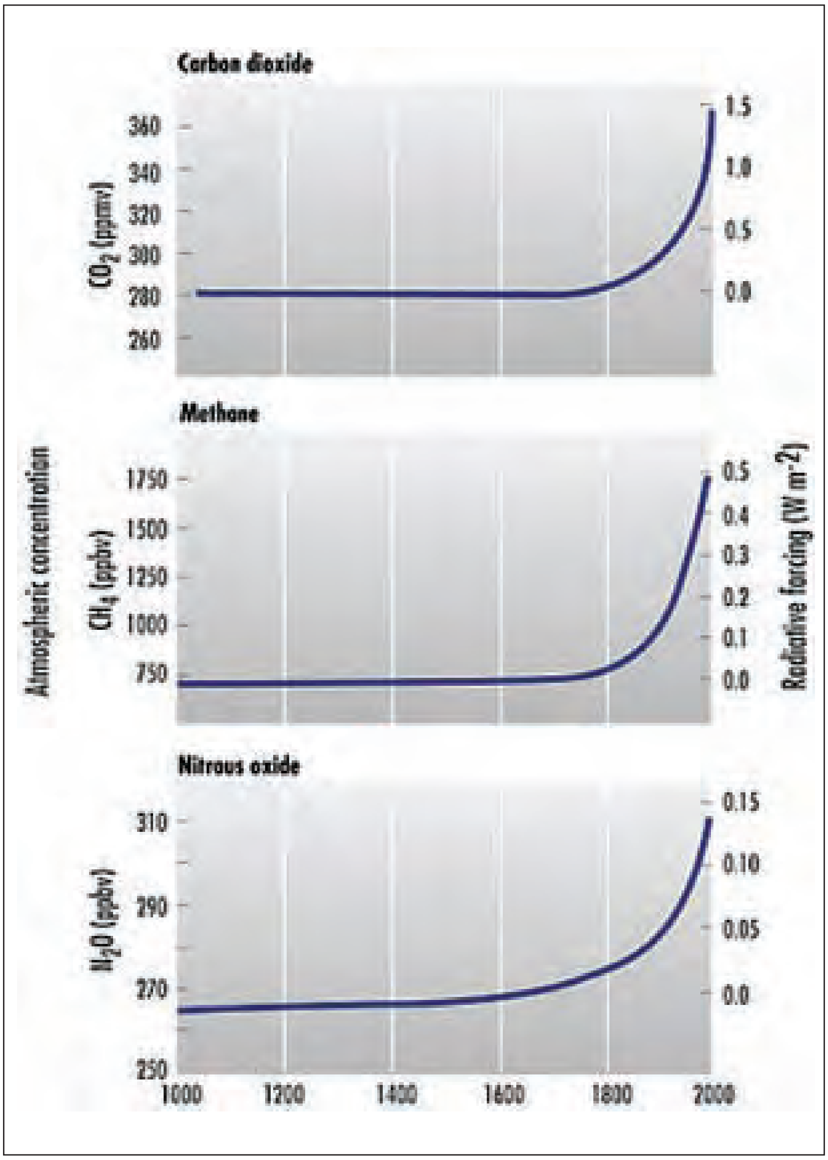
1.1 Climate change: present and future

We now know that the climate of the planet we all depend upon for survival is changing, and that the earth is warming at a rate unprecedented in recorded history.

Human activities have been altering the composition of the atmosphere, changing the balance of how much solar energy is trapped, and how much is reflected away from the earth. Burning fossil fuels has increased atmospheric concentrations of greenhouse gases such that current concentrations are the highest for the last 650,000 years. During the past 100 years, global average surface temperatures have increased by about 0.7˚C. The future we face is one of further warming, changes to rainfall, sea level rises, and increasing frequency of natural disasters.

There is evidence that this is already having an adverse impact on human health and will continue to do so in complex ways, which we are only beginning to understand. We must take action now to both prevent worsening of the problem and adapt to a range of impacts now and into the future.

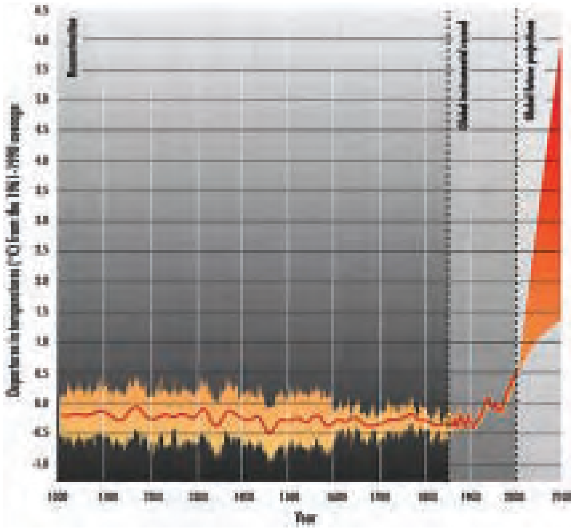
Figure 1: Atmospheric concentrations of carbon dioxide, methane and nitrous oxide over the last 1000 years (Bureau of Meteorology)



'Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in greenhouse gas concentrations.'

Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report 2007.

Figure 2: Projected global mean surface temperature changes in recent historical context (Bureau of Meteorology)

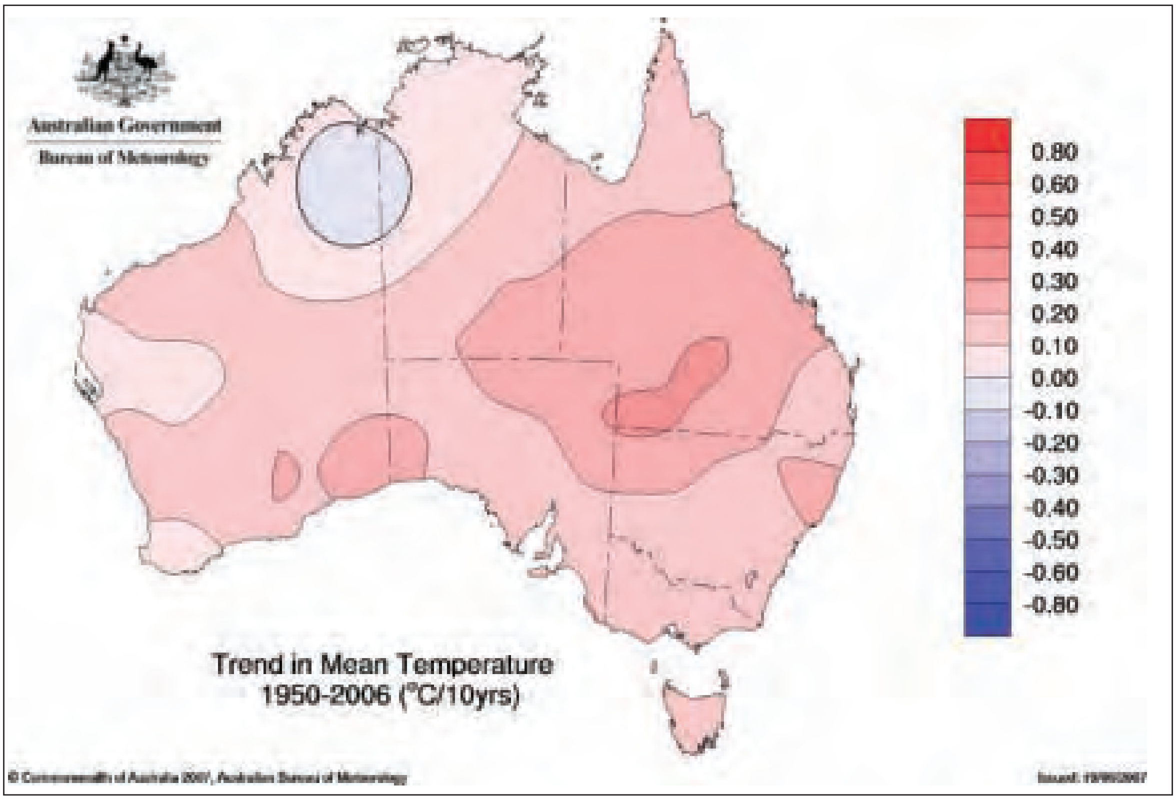


Over the next century, a global warming of 1.1–6.4˚C is predicted. History has shown that a warming of 1–2˚C can have dramatic consequences. Even the amount of warming to date has been associated with increasing heatwaves and floods, more intense droughts, retreat of glaciers, sea level rise, coral bleaching and disruption to ecosystems.

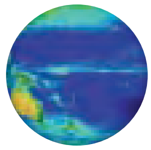
Once carbon dioxide is released into the atmosphere, it remains there for 50 to 200 years. Regardless of how well we manage to curb greenhouse emissions, some degree of climate change is inevitable and we will be forced to deal with the evolving impacts for many generations to come.

Australia's average surface temperatures have increased by approximately 0.9˚C from 1910 to 2002, with most of the change occurring since 1950. Projections for Australia are for water security problems to intensify with more frequent and intense droughts, increases in the severity and frequency of storms and coastal flooding, heatwaves and fires, significant loss of biodiversity, risks to major infrastructure, more blackouts, a decline in agriculture and forestry production. Many ecosystems in Australia are likely to be lost or severely damaged, with temperature increases of 1–2˚C, including the Great Barrier Reef, Kakadu, alpine zones and World Heritage rainforest areas.

Figure 3: Trend in mean temperature Australia 1950–2005 (Bureau of Meteorology)





1.2 Projections for Victoria

Climate predictions for Victoria by the CSIRO are for further increases in temperature, a decrease in rainfall, more severe droughts, less snow cover and frost, more heatwaves and increased bushfire activity.

By 2070 Melbourne's climate is likely to have warmed by 2˚C with 15 per cent less annual rainfall, creating a climate similar to Adelaide's climate now. The annual number of days in Melbourne on which the temperature exceeds 35˚C may increase by between three to 13 days by 2070, whereas for Mildura, the increase may be from nine to 41 days.

Although rainfall is predicted to be less in total, rainfall events will tend to be more intense in some regions with a greater risk of flash flooding. Rain-bearing weather systems appear to have shifted south and since the early 1970s, droughts have become more intense.

The amount of solar radiation reaching the ground is likely to increase. The average number of very high and extreme forest fire days in Victoria are expected to increase by 15 to 70 per cent by 2050. Unabated climate change could reduce average stream flow into Melbourne's main reservoirs by seven to 35 per cent by 2050.

The majority of Victoria's population lives within 50 kilometres of the coast. Coastal regions are likely to see increased risks of flooding and erosion as a result of rising sea levels and storm surges. Loss of biodiversity and ecosystem damage is predicted for many areas and a range of changes may occur in agriculture, forestry and fisheries.

2. Potential health impacts

2.1 Overview

Climate change is already contributing to the global burden of disease and premature death. The World Health Organisation estimates that climate changes over the past 30 years could already be causing loss of over 150,000 lives and approximately five million DALYs (disability-adjusted live years) per year throughout the world.

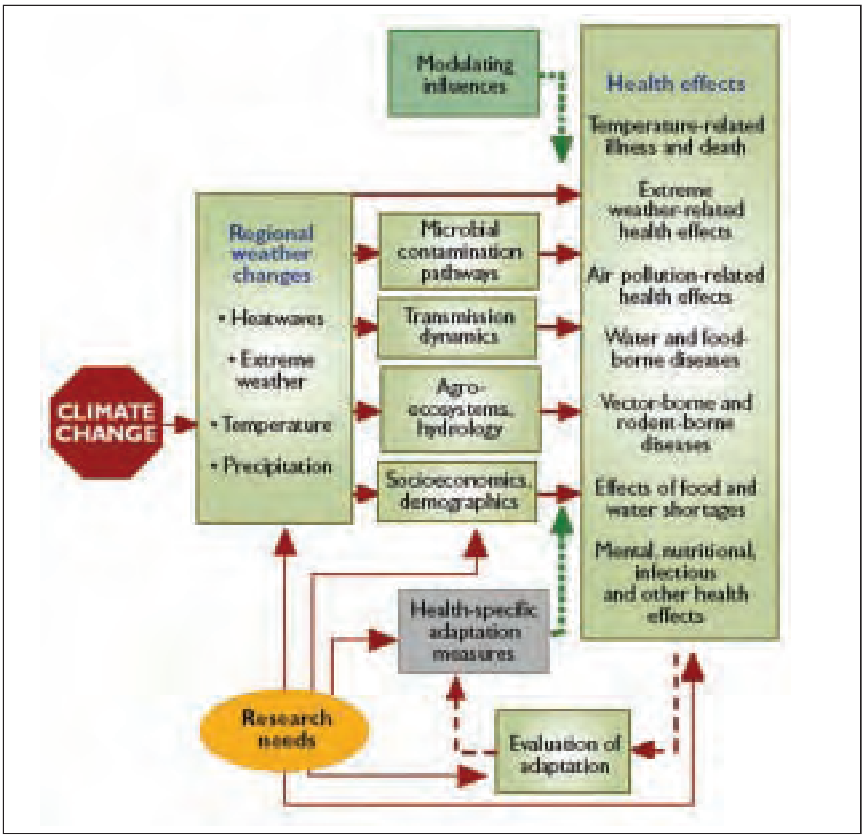
The projected changes to climate are likely to affect the health of millions of people throughout the world with:

- increases in malnutrition
- increased deaths, disease and injury from heatwaves, floods, storms, fires and droughts
- increases in diarrhoeal disease
- increased frequency of cardio-respiratory disease due to worsening air quality
- altered distribution of some disease vectors.

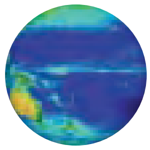
Some likely impacts of climate change are not difficult to predict, but those that are more indirect and involve complex interactions between the environment, microbes, animals and people are much harder to quantify. We can attempt to understand impacts by extrapolation from studies of the relationship between climate variables and health outcomes in human populations, or by using predictive computer models based on knowledge about these relationships in a variety of scenarios.

The figure below shows a simplified model of the potential health impacts of climate change.

Figure 4: Health impacts of climate change (WHO)





Climate change can affect human health directly (for example, thermal stress, injury and death in floods and storms) and indirectly through changes in the distribution of disease vectors (such as mosquitoes), food and water-borne disease, the quality and availability of food and water, and poor air quality. The actual health impacts will be strongly influenced by local environmental and socio-economic factors, and by the social, institutional, technological and behavioural adaptations made to reduce the full range of potential threats.

There is no longer uncertainty about the reality of climate change. However, the magnitude of the change may be over or underestimated in predictive models. Research on climate–health interactions has been increasing only in recent times, and there is still much to learn. Climate change research to date has focused mostly on thermal stress, extreme weather events, and infectious diseases, but little work has been done on the indirect impacts resulting in social, economic and demographic changes which are themselves determinants of health.

The Fourth IPCC report noted that the published evidence to date indicates that climate change is affecting the seasonality of some allergenic species as well as seasonal activity and distribution of some disease vectors. Climate plays an important role in the distribution of malaria, dengue, tick-borne diseases, cholera and some other diarrhoeal diseases. Heatwaves and flooding can have severe effects on health.

The urban poor, the elderly and children, traditional societies, subsistence farmers and coastal populations are some of those at greatest risk from the adverse impacts of climate change.

Overall, climate change may have some benefits, such as a reduction in cold-related mortality in some countries (not likely to be significant in Australia), but overall these are predicted to be greatly outweighed by the negative impacts.

In addition, climate change is only one of several concurrent global environmental changes that can simultaneously and interactively affect human health. For example, climate, human population movement and density, deforestation and land use changes, loss of biodiversity (for example, predators) and surface water fluctuations can all affect transmission of mosquito-borne diseases.

2.2 Climate extremes

2.2.1 Heat

Human beings survive within a range of optimum temperature, outside of which morbidity and mortality increases.

Globally heatwaves have become more common, and heat-related morbidity and mortality are predicted to accompany an increasing frequency and severity of extreme heat events. During a heatwave in Europe in August 2003 more than 35,000 excess deaths were reported. Since then many governments have implemented heat health prevention and response plans.

Although there is no standard definition of a heatwave, it can be considered an episode of sustained heat load known to affect human health. Similar temperatures can have different impacts on a population, depending on the duration of the heat event, the timing within the season, and background of acclimatization of the population. Heatwaves early in summer tend to have greater impacts than comparable temperatures later in the season.

In February 2004, two-thirds of continental Australia recorded maximum temperatures over 39°C. Temperatures reached 48.5°C in western NSW and the Queensland ambulance service recorded a 53 per cent increase in ambulance call-outs.

Extreme heat conditions occurred across Victoria on a number of days in January 2006. On one of these days the temperature reached 42.4°C in Melbourne and 80 people collapsed from heat exhaustion.

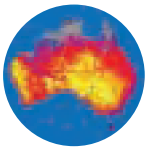
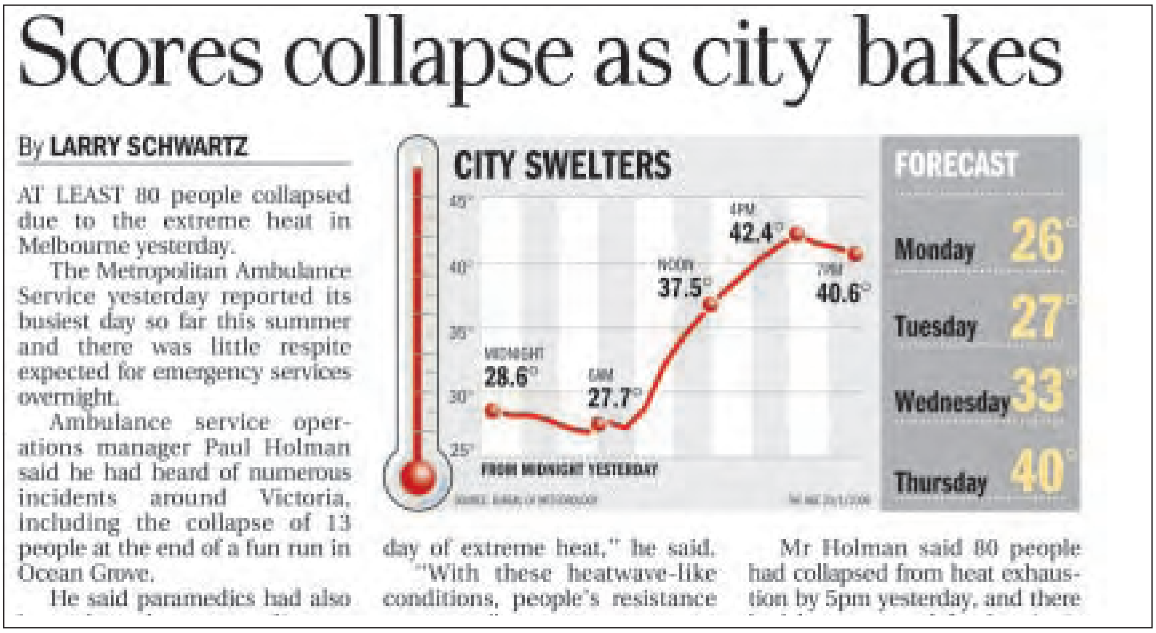


Figure 5: Headline from *The Age* newspaper January 2006 reproduced with permission



Scores collapse as city bakes

By **LARRY SCHWARTZ**

AT LEAST 80 people collapsed due to the extreme heat in Melbourne yesterday.

The Metropolitan Ambulance Service yesterday reported its busiest day so far this summer and there was little respite expected for emergency services overnight.

Ambulance service operations manager Paul Holman said he had heard of numerous incidents around Victoria, including the collapse of 13 people at the end of a fun run in Ocean Grove.

He said paramedics had also

day of extreme heat," he said.

"With these heatwave-like conditions, people's resistance

Mr Holman said 80 people had collapsed from heat exhaustion by 5pm yesterday, and there

Heat illness frequently occurs in those exercising outdoors, but it can occur in less fit people at lower levels of activity or at rest. The body can lose heat in a number of ways but evaporation of sweat is the most important way the body dissipates heat. Cardiovascular reserve is important as it determines the capacity to move heat for dissipation from the body core to the skin. The ability to thermoregulate the body tends to decrease with age.

Heatwaves have been described as the silent hidden disaster. This is because most of the excess deaths that occur during extreme heat are of the elderly and persons with pre-existing illness. The very old, the very young and the frail are the most susceptible. Being poor or socially isolated and urban living are also risk factors.

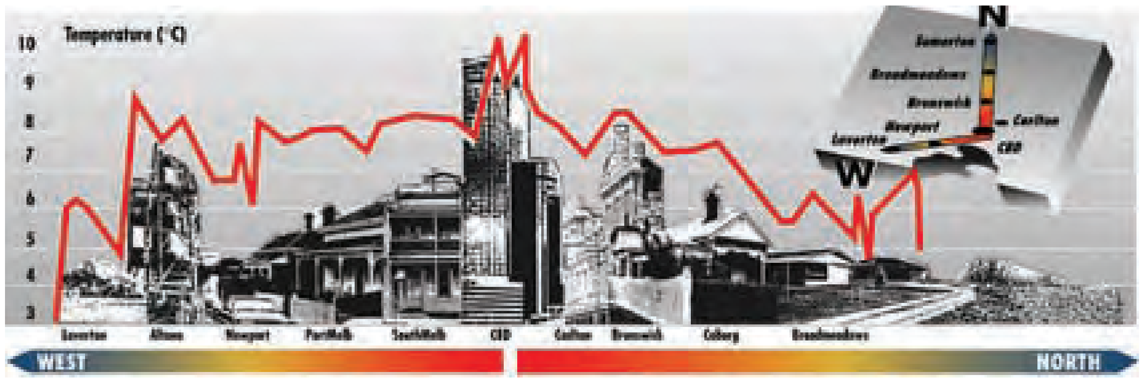
Although conditions such as heat exhaustion and heat stroke may be recorded in routinely collected health data they give a poor indication of the total impact of heat stress on a population. Mortality is primarily due to cardiovascular, cerebrovascular and respiratory disease.

In Australia, it is estimated that, there are currently more than 1,000 heat-related deaths annually in people aged over 65 years in Australian capital cities, with temperature-attributable death rates for Melbourne of 70 per 100,000 of population. Heat-related mortality rates in Australian cities are expected to increase substantially by 2050, taking into account demographic changes, with heat-related mortality for Melbourne likely to at least double.

Studies of heat-related morbidity have varied considerably. Heatwaves in the USA have been associated with increases in emergency hospital admissions. The 1995 Chicago heatwave was associated with an 11 per cent increase in emergency hospital admissions. In France during the 2003 heatwave, many hospitals were overwhelmed but in London only a 16 per cent increase in admissions for the over 75 age group was reported. Often people who die during heatwaves do so before admission to hospital.

Increasing urbanisation and aging of the population is likely to amplify the effects of climate change. Urban areas, where heat-retaining surfaces are concentrated, create a 'heat island effect' and cities can experience temperatures 5–11 °C warmer than the surrounding rural areas.

Figure 6: Temperatures across Melbourne on a still clear night showing the 'heat island' effect
(Bureau of Meteorology)



Heatwaves don't occur in isolation. They often occur in association with a number of other potential health threats such air pollution, drought, changes in water quality (for example, blue-green algal blooms) fires, and power failures.

In studies of heat-related mortality, air pollution is a confounder because it is associated with both daily variations in temperature and daily variations in mortality. However air pollution may also have a synergistic effect with heat on the body. Ozone and particulates tend to be high on high heat days.

2.2.2 Other extreme weather: wind, storms, floods

Globally the number of people killed, injured or made homeless by natural disasters has been increasing. This is likely to be a function of increased frequency of extreme climatic events, increased population vulnerability and better reporting.

From 1967-2005 the average annual cost of natural disasters is estimated to be over $100 million for Victoria (and over 10 times this amount for Australia). This comprises over $23 million for severe storms and over $40 million for floods.

Floods

The health impacts of flooding range from death, injury, infectious disease and toxic contamination, to mental health problems. Some populations may experience increased rates of diarrhoeal disease after flooding. Globally, increases in cryptosporidiosis, typhoid fever, cholera and leptosporosis have been documented.

Although the risk of infectious disease in high-income countries is generally low after floods, increases in diarrhoea and respiratory diseases have been reported and in the USA after Hurricane Katrina, faecal contamination of water supplies led to illness and some deaths. Chemical contamination with lead and volatile organic compounds also occurred, which highlights the risk of hazardous materials being released during flooding.

There is evidence that flooding can also have an adverse effect on mental health, causing anxiety and depressive illness, especially in the elderly and contributing to behavioral disorders in young children.

When sewerage systems are overwhelmed by heavy rainfall events, they are designed to release sewage into river systems to prevent backflow into houses. This provides a greater potential for contamination of watercourses.

Flash flooding in Melbourne 2003 (Courtesy 'The Age').

Benalla 1993. Image courtesy State Emergency Service, Victoria.

In Melbourne, flash flooding is likely to become more common. In December 2003, a storm in the north of Melbourne caused widespread flash flooding with damage to houses, cars, schools and shops. Floodwaters were two metres deep in some areas and 10 motorists who were trapped on the Eastern freeway had to be rescued by boat.

In late June 2007, parts of East and West Gippsland experienced severe flooding. The Mitchell, Tambo, Snowy, Cann,Thomson, Macalister, Avon and Genoa River systems were all affected, which brought flooding to several communities, including parts of Bairnsdale, Sale and Lakes Entrance.

Several of these river systems flow into the Gippsland Lakes system. King tides at the time exacerbated the flooding, as the flow of flood waters from the Gippsland Lakes was restricted. This flooding event was significantly greater than floods that occurred in the region in the mid 1990s.

Despite the flooding, drinking water supplies were maintained throughout the event. In West Gippsland, the flooding in Sale had the potential to disrupt operation of the local water treatment plant, but significant flood mitigation works by the local water business maintained the quality of the supply. The water supply to the town of Maffra was also threatened by flooding in the Macalister River in East Gippsland. The floodwaters broke a water transfer main, but drinking water could be trucked in to the affected residents.

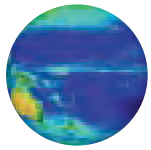
The effects of these floods on drinking water were far greater in communities not serviced by a town supply, where either rainwater tanks were washed away or contaminated floodwater infiltrated shallow groundwater supplies, contaminating the groundwater. This became an issue where landholders were relying on shallow bores as their sole source of domestic water.

The ability to supply clean water to areas affected by flooding will always be a challenge, particularly if the area affected is large, remote or is heavily populated.

The Victorian Emergency Services Commissioner led a whole-of-government recovery response to the floods. Other issues included failure of septic systems and food safety risks (due to flood water or power failure).

Potential problems in similar situations include changes in habitat favouring mosquitoes and/or rodents, exposure to sewage-contaminated water, mould growth in homes and injury from damaged infrastructure or flood debris. Losses to individuals and local economies and social dislocation can induce financial and mental stress.

The rainfall event that brought flooding to the Gippsland region also resulted in large volumes of water flowing into the reservoirs that form the raw water storages for Melbourne's drinking water supply. The catchment areas of reservoirs had been largely dry for the preceding eight years, so the rainwater carried large amounts of debris and sediment into the reservoirs.

This resulted in a significant increase in the turbidity of the stored water, which then resulted in boil water notices issued for some communities in the Upper Yarra Valley, who receive their drinking water almost directly from the affected Upper Yarra Reservoir. Ensuring such water was free of microbial contaminants was a challenge for both the affected water businesses and the health regulatory agency.

This particular event is likely to affect the Melbourne water supply system for months to come. The broader implication is that if the climate change models are correct, and the new reality is a drier climate, interspersed with extreme weather events, then turbidity events such as this one may become more common.

After the floods, with anticipation of increased mosquito numbers, the East Gippsland Shire received an additional $35,000 funding for mosquito management in addition to its normal programs. After the 1988 floods mosquito trapping indicated a rise in mosquito numbers of four or more times the number normally identified.

Storms

Changes in wind velocity and frequency and intensity of storms are difficult to predict, but there is evidence that warming of the oceans is increasing the intensity of cyclones. One modelling scenario predicts an increase of frequency of severe tropical cyclones on the eastern Australian coast by 22 per cent by 2050.

Tropical cyclone Larry, which hit Queensland in 2006, caused significant damage to houses, business, utilities, infrastructure, crops and forests, and subsequent economic losses.

The Sydney hailstorm of 1999, was, except for drought, the most costly natural disaster in Australian history and caused a huge drain on emergency services.

In June 2007 a severe storm swept through the Hunter and Central Coast regions of NSW, resulting in widespread flooding and damage. Five people died, 2,000 homes were without power and 4,000 without water, thousands of calls were made to emergency services, and an oil freighter was beached off a major city.

Image courtesy State Emergency Service, Victoria.

Image courtesy Emergency Management Australia.

Image courtesy State Emergency Service, Victoria.

Coopers creek fire 2006. Image courtesy DSE.

Department of Sustainability and Environment (DSE), Country Fire Authority and New Zealand fire fighters. Image courtesy DSE Victoria.

2.3 Fire

The average annual cost of fires to Victoria in 1967–2005 is estimated to be over $36 million. In south-east Australia, the frequency of very high and extreme fire danger days is likely to rise by 4–25 per cent by 2020 and 15-70 per cent by 2050.

Forest and bush fires can cause injury, burns and damage from smoke inhalation, and exacerbate asthma and other respiratory and cardiovascular conditions. This can stretch the capacity of health care systems to respond.

Toxic gaseous and particulate pollutants are released into the atmosphere and can affect air quality over many kilometres. Recent bushfires have contributed to some severe air pollution in the regions and in Melbourne.

During the 2002–03 bushfires, Melbourne had 10 days exceeding air quality objectives for particulates (PM_{10}) and two for ozone. During the 2006–07 bushfires there were 15 days exceedence for particulates and four for ozone. The Latrobe Valley and Wangaratta recorded even greater exceedence for particulate pollution. Some measurements of air quality in Melbourne, the Latrobe Valley and north-east Victoria reached four to five times the air quality standard for particulates during the most recent bushfires.

Although less work has been undertaken on the health effects of particulate pollution from bushfires and dust than from urban air pollution, some Australian research has found a significant increase in asthma presentations with increasing particulate (PM_{10}) concentrations from bushfire smoke. It has been suggested that each increase of 10ug/m^3 in the ambient concentration of respirable particulates is associated with a 3 per cent increase in exacerbations of asthma.

During the Canberra bushfires of January 2003, 500 houses were destroyed, four people were killed and hundreds injured. Health services were stretched to capacity and three of the city's four dams were contaminated for several months by sediment-laden runoff.

Water quality can be significantly impacted by ash and debris entering rivers and reservoirs after catchment areas are burnt. In many cases it is the first major rain event that follows the bushfire that washes the majority of ash and debris into the waterway. Alternative drinking water supplies may need to be supplied to large numbers of people.

A more subtle effect, which was documented by the CSIRO after the Canberra fires, is that water yield from some catchments may be reduced after fire. This seems to be related to new growth having higher water demands than established growth. The longer-term implication is if water yield from catchment areas is already under stress, then a further reduction through fire may have serious consequences.

Over a two week period in early 2006 over 100 bushfires burned in Victoria, with the most severe fires in the Grampians, Anakie, Erica and Kinglake areas, resulting in the loss of around 26 houses and the deaths of four people. At Halls Gap, raw water was introduced into the water supply system to assist fire-fighting efforts. Residents were provided with bottled water until the quality of the town supply was verified safe.

Where there were concerns about the quality of the drinking in other supplies affected by bushfires, precautionary boil water notices were issued by the relevant water businesses.

Air quality was affected by bushfire smoke in the Mildura and Latrobe Valley regions resulting in public health warnings issued to the affected communities.

Food safety can be compromised by power failures and physical and mental wellbeing can be threatened in large numbers of people engaged in fire fighting or evacuations.

The more recent 2006–07 bushfire season in Victoria was one of the worst on record, with fires starting earlier and burning longer. In total, around 19,000 people (14,000 of these were volunteers) worked on suppressing the fires over 69 days. The State Government committed a $138 million package to manage the fires and assist with recovery.

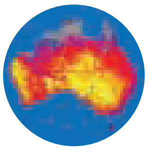
As was the case at Halls Gap, raw water was introduced into the drinking water supply systems of Mt Beauty and Whitfield, to support fire-fighting efforts. Again, boil water notices were issued to residents.

The fires had a severe impact on the catchments of most rivers in Gippsland and north-east Victoria, and exacerbated the effects of the Gippsland floods of June and July 2007. The amount of sediment that was present in the affected waterways provided water businesses with additional treatment challenges.

DSE fire fighter extinguishing fires near Bruthen 2007. Image courtesy DSE Victoria.

Satellite image of bushfire smoke covering Victoria. Image courtesy NASA.

For an extended period Melbourne's water catchments were under direct threat, which could have had a major impact on the quality of Melbourne's water supply. It is not impossible that a future bushfire will affect these catchment areas, and the consequences for Melbourne would be profound.



2.4 Drought

Globally, the effect of drought includes death, malnutrition, infections and respiratory disease, and drought often acts as a trigger for population movements, which can create another set of health issues.

In Australia, mental health and economic stress are major areas of concern in relation to drought. Increased levels of anxiety and depression occur among farmers experiencing crop failures and stock losses due to drought. Diminished incomes and reduced social participation can impact upon mental health. Although suicide rates are higher in men living in rural areas, there is a paucity of data on health issues in rural and remote areas related to drought.

Courtesy of EMA.

Courtesy of DSE. Mass eel deaths Lake Modewarre.

In Victoria, some rural townships have had to rely on tankers to deliver water in summer months. The Murray-Darling Basin is Australia's largest river basin, accounting for about 70 per cent of irrigated crops and pastures. Annual stream flow in the Basin is likely to fall 10-25 per cent by 2050, with water scarcity liable to have major impacts on the price and availability of fresh food.

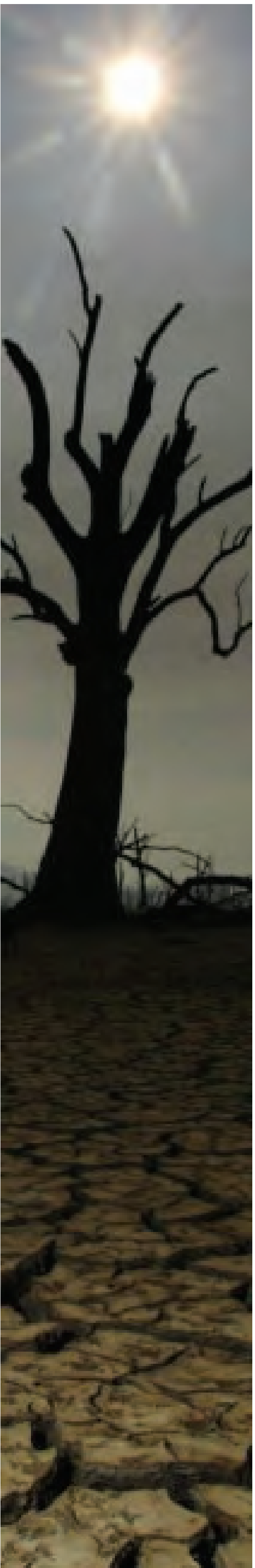
Reductions in rainfall leading to low river flows can reduce effluent dilution and increase the concentration of pathogens. Water scarcity drives the demand for technologies and use of alternative water sources, such as desalination and potable reuse of recycled water, with the potential to introduce new health threats.

The transmission of some mosquito-borne diseases can be affected by drought events. Activity may be reduced or increased (for example, by stagnant water or loss of predators).

Water shortages are likely to reduce availability for gardens and recreational green spaces, which will have impacts on recreational opportunities and social connectedness.

They may also result in power shortages and increasing power costs, as coal and hydro generation requires large amounts of water. This could have flow-on effects in many areas, including food safety and availability of air-conditioning to counteract heat stress.

In recent years some land-locked lakes in Victoria, such as Lake Modewarre, have seen large numbers of eel deaths in the summer, sometimes in association with harmful algal blooms. The Environmental Protection Authority (EPA) has indicated this may be related to the lakes drying up, with higher water temperatures and increasing salinity.



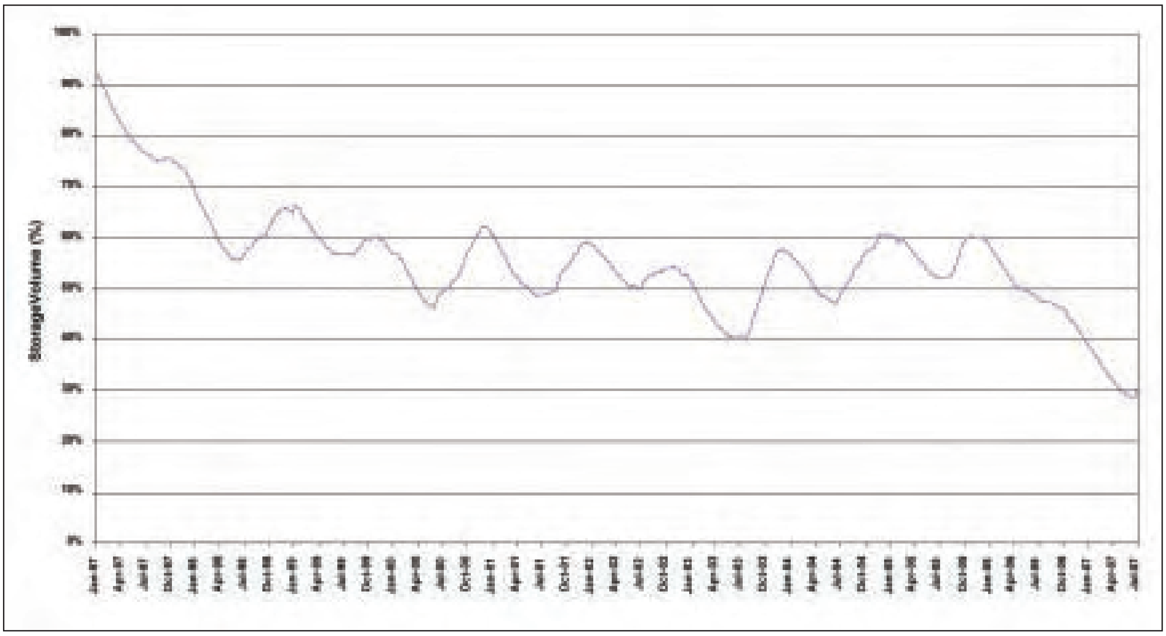
Courtesy The Age News, picture by Jason South

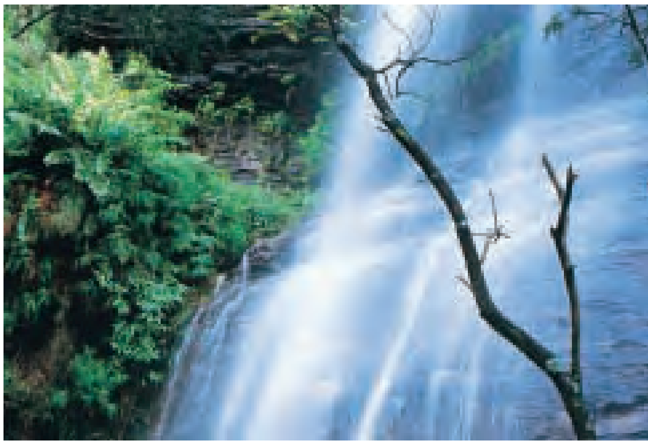
Dust storms may have adverse effects on respiratory health. Associations have been found between particle exposure from dust storms and exacerbation of asthma symptoms. Mildura currently has the highest recorded particle count for dust particles in the state.

The figure below shows the volume of water in storage in Melbourne's drinking water supplies for the period January 1997 to July 2007, indicating a gradual decline over the past ten years.

Weather 2006. Dust storm blankets Mildura, March 2003. SMH Picture by NICK MOIR Image courtesy Fairfax publishing.

Figure 7: Water in Melbourne's storage 1997–2007 (Courtesy DSE)





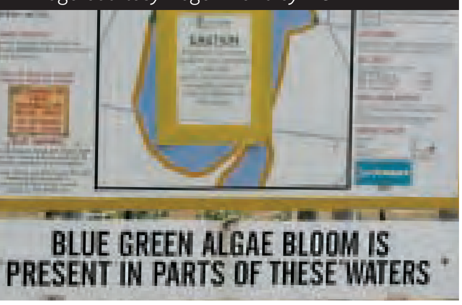
2.5 Water quality

Although our climate will be drier, when rainfall does occur it is likely to occur in heavy falls. Intense rainfall, especially after drought periods, can facilitate transport and dissemination of pathogens into waterways, and temperature can affect survival and growth. Disease can be spread through either inadequately treated drinking water or recreational water.

Waterborne disease, particularly gastroenteritis, may be caused by a range of organisms. These include *norovirus, Giardia, Cryptosporidium, Campylobacter, E.coli* and *Shigella*. It has been reported that more than 50 per cent of waterborne disease outbreaks in the USA between 1948 and 1994 were preceded by extreme precipitation events. Examples of waterborne outbreaks after heavy rainfall include a cryptosporidiosis outbreak in Milwaukee, USA in 1993, and an *E.coli* outbreak in Walkerton, Canada in 2000, each affecting thousands of people.

Eutrophication, or nutrient enrichment, is a major water quality problem in Australia. It fosters the development of harmful algal blooms caused by the proliferation of blue-green algae (cyanobacteria). These blooms are likely to become more frequent and last longer with climate change, as they thrive in conditions of high temperature and low environmental flows. They have the potential to produce powerful biotoxins, which can pose a threat to human health through drinking water and recreational water use, and can affect fish and livestock that may be used for food.

Blue-green algae warning sign. Image courtesy Roger McAuley DSE



Blue-green algae. Image courtesy Grampians Wimmera Mallee Water.

Three main types of toxin can be produced:

(1) endotoxins which cause skin rashes, eye irritation and gastroenteritis

(2) neurotoxins which can damage nerves and affect muscles

(3) hepatotoxins which can damage the liver, and may also increase the risk of some types of cancer long-term.

In Wycheproof in September 2006, an algal bloom occurred on the raw water storage of the town's water supply, depriving the town's 730 residents of water for drinking or washing for four weeks. The water retail business had to provide bottled water and then deliver water by tanker for drinking and personal hygiene purposes until the bloom could be brought under control.

After extensive testing, the bloom was shown not to be producing toxins, but the testing regime is long and complex, prolonging the time the water was unable to be used. Even though there were no toxins detected at the time, there were significant taste and odour issues associated with the bloom.

In March 2007, a toxin-producing bloom occurred on the raw water storage that provides water to Aireys Inlet. Water was brought in by tanker until the retail water business could verify that the treatment processes at the Aireys Inlet Water Treatment Plant could effectively remove the toxins.

2.6 Food safety and security

Increasing temperatures are predicted to facilitate transmission of organisms that commonly cause food poisoning, such as *Salmonella* and *Campylobacter*. Some studies have reported an approximately linear increase in notifications for *Salmonella* with each degree increase in ambient temperature.

In 2005 the Department of Human Services received notifications for 202 outbreaks of gastrointestinal illness affecting at least 4,000 people. The organisms most commonly identified as responsible for the outbreaks were *norovirus, Salmonella and Cryptosporidium*. The Department received notifications for 1,421 cases of salmonellosis in that year.

Flies, and other pests which may affect food safety, tend to increase in abundance in warmer temperatures.

Plants and animals can take up toxins produced by cyanobacteria, which thrive in conditions of warmer temperatures and low flows. Fish, prawns and shellfish can all accumulate toxins and these may be at levels to cause illness and even death in humans.

Warmer seas and coral bleaching may increase ciguatera poisoning. This is a serious form of food poisoning associated with eating fish that have accumulated toxins from dinoflagellates growing on bleached and damaged coral.

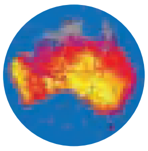
Some *Vibrio* bacteria (*parahaemolyticus, vulnificus*) are capable of causing large outbreaks of food poisoning if they contaminate shellfish and their abundance is dependent on the salinity and temperature of coastal water.

Increasing temperatures may indirectly increase human exposure to some environmental contaminants in food. For example, mercury concentrations in some species of fish are already a health issue requiring consumption advice. Increasing sea temperatures are projected to increase the rate of mercury methylation in fish.

Mycotoxins in food may be a problem with increases in temperature and humidity. These include aflatoxins produced by fungi on grains and nuts, which are toxic to the liver and carcinogenic.

Crop damages and stock losses from drought and severe weather events are likely to have impacts on the cost and availability of food, increasing present health inequalities in this area. Where shortages need to be met by importing foodstuffs, there is the additional risk of importing pests and diseases.

Where patterns of food production change, there may also be changes in the use of agricultural chemicals or genetically modified crops, which may subsequently have human health impacts.



Thick blanket of smoke from bushfires covering Melbourne CBD, The Age 13 December 2006. Picture by Paul Rovere

Air pollution in Wangaratta during the 2007 bushfires.

2.7 Air quality

2.7.1 Pollutants

The main sources of urban air pollution in Australia are vehicle emissions, industrial pollution and wood smoke from home heating. Major components of air pollution include particulate matter (PM), sulphur dioxide, nitrogen oxides, carbon monoxide, ozone and volatile organic compounds. The impact of smoke from bushfires and dust from drought-affected areas has already been noted.

Concentrations of air pollutants are affected by temperature and humidity. Urban air pollution is associated with increased mortality and cardiorespiratory morbidity, and health effects occur even at exposure levels within current air quality guidelines.

Increasing concentrations of pollutants likely with climate change could have significant population health impacts. Some epidemiological research from the USA has found significant associations between annual average particle pollution levels (PM_{10} or $PM_{2.5}$) and annual all-cause mortality rates. An average increase of 10ug/m^3 was associated with a 3-4 per cent increase in mortality.

Associations have been found between particle pollution and hospital admissions, particularly for asthma and chronic obstructive pulmonary disease, and also for cardiovascular diseases.

Concentrations of ozone, a respiratory irritant, are increasing in most urban regions. A study of 15 US cities predicted that the average number of days exceeding the eight-hour ozone standard would increase by 68 per cent by the 2050s. Exposure to high ozone levels is associated with a range of respiratory diseases and with premature mortality. It can affect not only those with pre-existing lung conditions, but also healthy people.

Ragweed pollen courtesy CSIRO.

2.7.2 Aeroallergens

Warmer temperatures and increased levels of carbon dioxide in the atmosphere can promote the growth of some plants and fungi known to be common causes of allergy when pollen or spores are inhaled. An increase in these aeroallergens is likely to contribute to increased rates of asthma and hay fever.

Ragweed, an invasive plant species with allergenic pollen, is spreading in several parts of the world, and there is evidence that increases in temperature and carbon dioxide concentrations increase ragweed pollen production and prolong the ragweed pollen season.

Some studies have suggested that air pollutants and aeroallergens may interact to contribute to respiratory allergic diseases.

2.8 Vector–borne disease

Vector-borne diseases are infections transmitted by the bite of arthropods such as mosquitoes, ticks, fleas and sandflies. There is already some evidence of changes in the distribution of ticks and mosquitoes in some countries in relation to climate change. Reproduction and survival rates are strongly affected by fluctuations in temperature, however temperature is only one of the many factors that determine the dynamics of disease transmission.

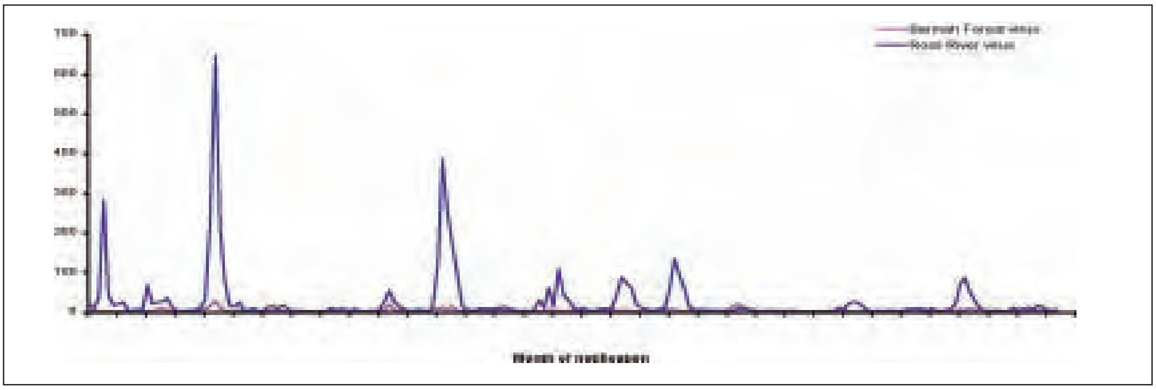
Malaria is no longer endemic in Australia, but it is in 92 other countries, affecting millions of people throughout the world, and a risk to Australians travelling abroad. A number of studies have reported associations between variability in temperature and malaria transmission in the African highlands. However the ecology of the vector is complex and a number of other factors such as HIV infection and drug resistance complicate a better understanding of the relationship between climate change and the spread of malaria. In 2005, 108 cases of malaria were reported to the Department of Human Services, a third of these in newly arrived refugees.

Dengue is the world's most important vector-borne viral disease, with approximately one third of the world's population living in regions where the climate is suitable for transmission. Although high rainfall or high temperature can cause an increase in transmission, so can drought in some circumstances where household water storages provide favourable breeding sites. Transmission of dengue may increase in northern Australia and Victorians holidaying there could be affected.

The most common mosquito-borne disease in Australia is epidemic polyarthritis, caused by Ross River virus (RRV) or Barmah Forest virus (BFV). While it is not a life-threatening disease, it can cause significant morbidity. Several studies have identified a relationship between climate and the breeding and survival of the vector mosquitoes for RRV.

Changes to the transmission of the disease are possible but the nature of these changes will vary by geographic region and are not yet clearly mapped. Rising sea levels may favour conditions for the vector in coastal areas where most of the Australian population live, and heavy rainfall following prolonged drought may provide favourable conditions for epidemics. Queensland has recently reported a large increase in RRV notifications following heavy rain in August 2007, which was preceded by a long dry spell.

Figure 8: Notified cases of Ross River Virus and Barmah Forest Virus disease in Victoria by month 1991–2007



Murray Valley Encephalitis is a rare but very serious disease. The most recent outbreak in temperate areas of Australia was in the Murray Valley in 1974 following marked flooding in the area.

2.9 Other infectious diseases

Diseases transmitted by rodents can increase during heavy rainfall and flooding. Examples are hantavirus pulmonary syndrome in Central America, and leptospirosis in a number of countries including Australia.

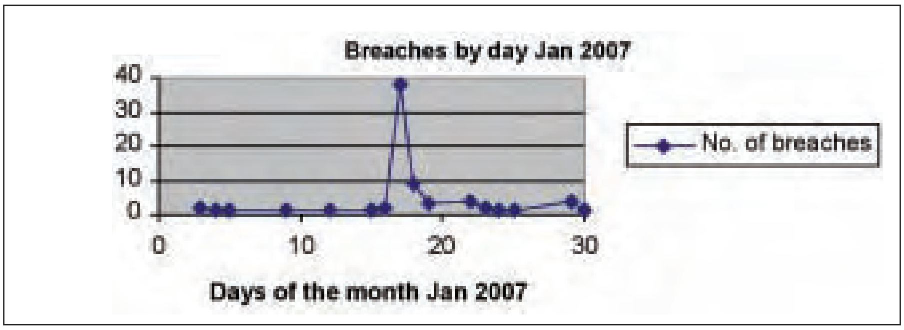
Other animals may become disease vectors with significant environmental change. A recent example is that of fruit bats driven by loss of habitat due to land clearing, drought and fires to seek food in farmed areas where they triggered an epidemic of Nipah virus in Malaysia and surrounding countries.

There may be changes in the incidence of Legionnaire's disease with increasing use of air-conditioning and use of mulch for water conservation.

It is possible that changes to climate may allow new diseases to be introduced and become established.

Climate change may lead to increasing breakdowns in the maintenance of the vaccine cold chain necessary for control of vaccine-preventable disease. A recent Department of Human Services study of vaccine cold chain breaches reported in 2006–2007 showed a large rise in reports due to very hot weather conditions and electrical power blackouts at the time of fires in north-eastern Victoria. The consequence of freezing or heating vaccines beyond the optimal temperature range may be an increase in disease (if ineffective vaccines are used) or cost (if the vaccines have to be discarded and new ones purchased). The average cost per vaccine cold chain breach in this study was approximately $3,900.

Figure 9: Vaccine cold chain breaches reported January 2007 showing peak associated with power disruptions from bushfires.



2.10 Ultraviolet radiation

Stratospheric ozone depletion is a separate problem to climate change, but there are links between them. Evidence suggests that global warming is likely to result in increased stratospheric ozone depletion. This would lead to increased exposure to UV radiation, potentially contributing to a higher incidence of skin cancer, melanoma and cataract.

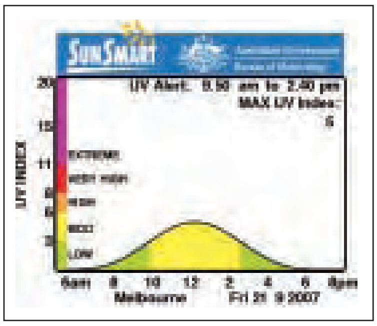
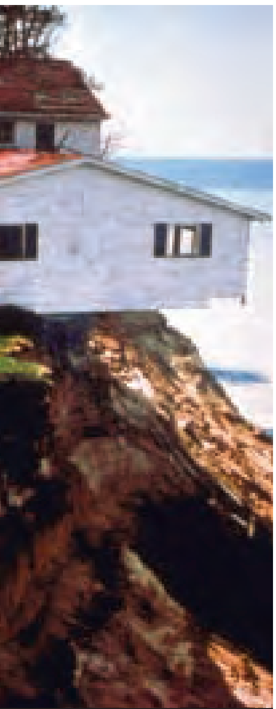


Image courtesy SunSmart Victoria.

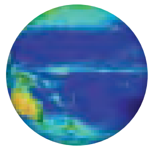
2.11 Sea level rise

In low lying areas, a rise in sea level may be associated with increased flooding, intrusion of saltwater and coastal erosion. Coastal freshwater aquifers may become saline, and stormwater and sewage disposal may be disrupted.

Population growth in the Asia-Pacific region combined with a one-metre rise in sea level is likely to affect 200–450 million people. Large numbers of displaced people becoming environmental refugees may present significant public health problems to countries such as Australia and New Zealand, and may increase the potential for conflict in the region.


Picture courtesy EMA.

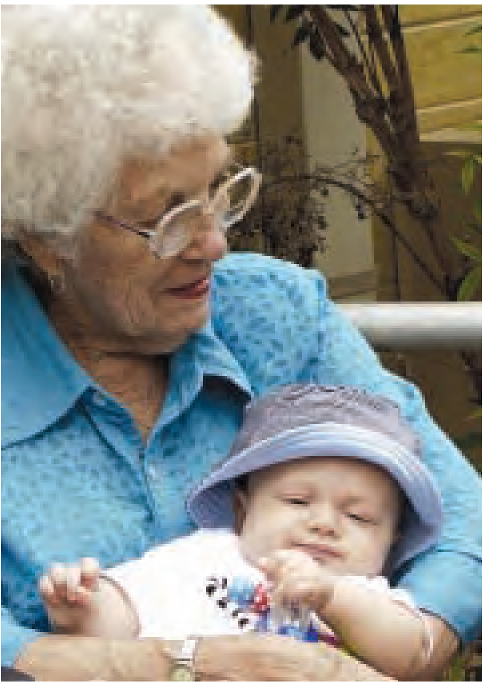


3. Adaptation: understanding vulnerability and building resilience

3.1 Defining adaptation and vulnerability

Primary prevention of the health impacts of climate change lie in mitigation and abating global greenhouse gas emissions. However, secondary prevention is also necessary in the form of adaptation. Adaptation is a response strategy to minimise the potential impacts of climate change.



The adaptive capacity is the ability of a system to adjust to climate change, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. Success in mitigating greenhouse gas emissions will determine how great the changes we will need to adapt to will be.

A population's vulnerability to climate change depends on factors such as population density and age distribution, economic development, food availability, income level and distribution, local environmental conditions and geography, pre-existing health status, and quality and availability of public health care.

The developing world, with only 10 per cent of the world's health resources, already carries 90 per cent of the disease burden, and climate change will disproportionately affect those already vulnerable.

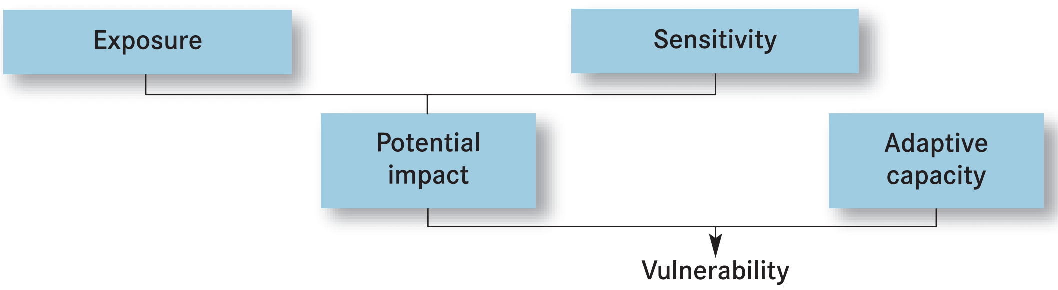
However, high-income countries are not immune from the health impacts of climate change. Australia's population is aging and becoming more urbanised. The proportion of Australians aged 65 years and over is likely to increase from 13 per cent in 2003 to 27 per cent in 2051.

Energy consumption in Australia is projected to grow 2.1 per cent per year on average. An increased demand for emergency services is highly likely, as is increased stress on the health care system.

Vulnerable groups in Australia are likely to include the elderly, the chronically ill, the socio-economically disadvantaged, indigenous communities, those with poor access to essential services such as good housing and adequate fresh water, and those whose economic prosperity depends heavily on climatic conditions.

Prioritising adaptation actions requires an understanding of vulnerability, which is a function of exposure to climatic factors, sensitivity to change and capacity to adapt to that change.

Figure 10: The components of vulnerability



Source: Adapted from D. Schroter and the ATEAM consortium 2004, *Global change vulnerability – assessing the European man–environment system*, Potsdam Institute for Climate Impact Research from Australian Greenhouse Office.

3.2 Approaches to adaptation

Adaptation can be implemented at a number of levels–national, community and individual. Adaptation strategies can enhance the resilience of vulnerable populations in a number of ways: public education and awareness-raising, creation of appropriate legal frameworks and institutions, encouraging supportive environments for healthy behaviour, development of infrastructure, research and surveillance, and medical and technical responses. Effective strategies need intersectoral and cross-sectoral collaboration.

One of the most important and cost-effective adaptation measures is the maintenance of a strong public health infrastructure. This includes public health training, effective surveillance and emergency response and high quality prevention and control programs. Adaptation research to date has indicated that many measures can be built upon well-established public health approaches.

Key obstacles to adaptation include a lack of awareness of the potential health impacts of climate change, a perception that the problem is too big or distant, a perception that the solutions are outside of health sector competence and control, competing priorities and a lack of a strategic framework.

3.3 Health co-benefits

Many adaptive measures have benefits beyond those associated with climate change. For example, reducing air pollution would not only help to minimise climate change, but could also reduce cardio-respiratory hospital admissions and deaths. It has been estimated that a 50 per cent reduction in vehicle-related emissions in the combined regions of Sydney and Melbourne could avert 300–500 premature deaths annually in those cities from air pollution.

Encouraging people to walk or cycle rather than drive is consistent with current strategies to encourage a more active lifestyle for the reduction of cardiovascular disease and diabetes.

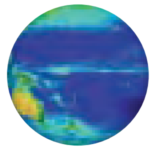
Efforts to reduce isolation of those at risk of heat stress could have a range of other benefits for improving mental health and social capital. Adaptation measures should as far as possible be integrated with other health strategies.

3.4 Frameworks for adaptation at the national level

A number of countries have undertaken health impact assessments and developed national frameworks for adaptation. The Canadian National Climate Change Adaptation Framework developed in 2005 noted the following:

- To be most effective, adaptation should be proactive – waiting for impacts to occur before making adaptive changes is essentially a non-strategy, likely to be more costly and inefficient.
- Governments have a critical role in adaptation, both as adaptors themselves and as catalysts to encourage and facilitate adaptation in other sectors of society.
- Governments can act now – the uncertainties about the extent and speed of climate change should not be an impediment to action.
- Collaboration between governments and with other stakeholders is essential for adaptation planning.



The approach was to first assess the vulnerabilities and adaptive capacities of different regions, communities and population groups and then to identify and select the most appropriate response strategies. This process is well suited to being part of an integrated risk-management framework.

Key findings from the Canadian experience have been to recommend that climate change is integrated into existing frameworks, rather then it being addressed as a separate issue, expanding existing monitoring, reporting and surveillance networks to include climate-related health impacts and increase and improve professional and public education about adaptive actions.

The Council of Australian Governments (COAG) requested development of a National Adaptation Framework in 2006 to help prepare Australian governments, industries and communities for the unavoidable impacts of climate change. Potential areas of action include the establishment of an Australian Centre for Climate Change Adaptation, and development of heatwave warning and response systems.

A National Action Plan on Climate Change and Health was proposed to include research on impacts on physical and mental health and identification of key vulnerabilities, assessment of the capacity of the public health system and the hospital system to respond, and incorporation of the potential for impacts on health into community and public health education programs.

3.5 The Victorian adaptation framework

In 2006, the Victorian Government released the environmental sustainability action statement *Our environment, our future*, with the development of mitigation and adaptation strategies to reduce climate impacts as major objectives. The Victorian Climate Change Adaptation Program was established as a whole-of-government approach to coordinate the actions identified in this document.

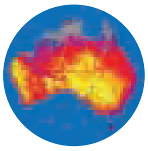
The strategies of the Victorian Climate Change Adaptation Program include:

- identifying likely impacts of climate change for Victoria
- assessing implications for the most vulnerable sectors, assets, regions and communities
- communicating potential impacts and risks to key audiences
- enabling effective stakeholder engagement
- building capacity of communities, government and businesses to adapt
- developing decision-making processes and risk management strategies to deal with the uncertainties of the timing and extent of climate change.

3.6 Examples of Victorian adaptation responses

A number of adaptation responses to climate change health impacts are underway–responses to drought and heatwaves are some examples.

The Victorian Government has provided funding of $3.1 million for the current financial year for the *Sustaining Community Wellbeing in Drought* initiative to support rural and regional Victoria in adapting to the social and mental health impacts of drought. This initiative includes counselling for rural communities, a drought personal support line, health promotion and planning through primary care partnerships, skills development across health and community service practitioners, and funding for the delivery of *Sustainable Farm Families*, a comprehensive health education and development program for farming families.



Adaptation to heat is a priority area of work currently being undertaken by the Department of Human Services in collaboration with other agencies such as the Department of Sustainability and the Environment (DSE), academic institutions and the Bureau of Meteorology. Strategies to adapt to heat include educating vulnerable groups and those responsible for them, warning of imminent heatwaves, and protecting vulnerable groups with appropriate plans and responses.

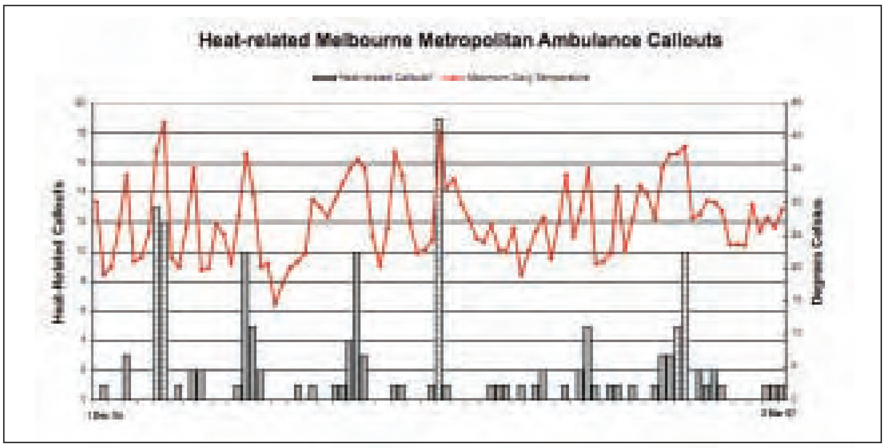
Internationally, heatwave plans have been developed in a number of cities, with evidence of effectiveness in reducing heat-related morbidity and mortality. Heatwave plans typically consist of a heatwave warning system, public information on how to prevent heat stress, and community-level interventions such as outreach to vulnerable people or provision of cool areas for refuge.

The draft Victorian Heatwave Strategy aims to improve understanding of the impacts of heatwaves on mortality and morbidity, develop a state heatwave plan encompassing a heat health warning system and heat health surveillance, and pilot and develop local heatwave response plans through local government.

Preliminary work has developed a threshold for a heat warning system for Melbourne, based on modelling of local mortality and temperature associations. Discussions have begun with the Bureau of Meteorology on the optimal model for a heatwave warning system. Research has been commissioned on understanding the information needs for carers of the elderly during extreme heat events.

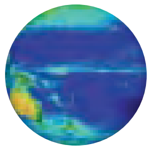
During the 2006–07 summer a pilot heat health surveillance system was initiated for metropolitan ambulance call-outs and after-hours GP locum calls for Melbourne in an attempt to improve understanding of heat impacts on morbidity and health service utilisation.

Figure 11: Heat-related Metropolitan Ambulance Service callouts for Melbourne 2006–07 summer and maximum daily temperatures



These and a number of other initiatives provide a basis for ongoing adaptation strategies for the state, but there is scope for a much greater width and breadth of activity.



4. Uncertainty and knowledge gaps

Uncertainties exist about the potential magnitude, timing and effects of climate change, the sensitivity of particular health outcomes to climatic conditions, and the future socio-economic and technological changes in society.

There is often uncertainty about climate change projections at the local level. Many climate change projections are necessarily large scale, but local patterns of climate are strongly influenced by regional topography. Large water bodies, coastlines and other geographic features may be important determinants of disease ecology. There is also limited knowledge about system dynamics and the adaptive capacity of natural systems.

Uncertainty, however, is no excuse for inaction.

There are gaps in our ability to understand the impacts that climate change may have on human health, such as a lack of appropriate longitudinal health data in relation to climate. Although considerable advances have been made in modelling capacity, these have been mainly restricted to extremes of heat, air pollution and a few infectious diseases.

Little research has been done on the indirect effects of climate change leading to social, economic, and demographic disruptions and the flow-on health effects from these.

Research can establish baseline relationships between climate and health, seek evidence of the early effects of climate change, develop scenario-based predictive models, evaluate adaptation options, and estimate costs and benefits as a guide for policy-makers.

Further research is needed in the following areas:

- heat–improved early prediction of heat episodes, modelling of temperature–mortality relationships, impacts on morbidity and health service utilisation, interaction with air pollution, evaluation of protective measures and adaptive strategies
- natural disasters–early warning, longer-term health effects such as mental health, and effects on infrastructure such as drinking water and waste disposal.
- drought and bushfires–assessment of direct and indirect effects, and better understanding of the health effects of bushfire smoke and dust storms
- air pollution–better assessment of exposures, long-term health impacts of exposure to ozone and ultrafine particles and the interaction of different pollutants and aeroallergens
- water or food borne disease–better surveillance and prevention, improved laboratory methods for identification of organisms in water
- recreational water and recycled water–improved understanding of the associated health risks
- patterns of drinking water access across Victoria, including access to bore water
- cyanobacterial toxins–improved identification and knowledge of their direct and indirect human health effects
- algal blooms–improved knowledge of the predictors of increasing algal blooms and the economic impacts
- vector-borne disease–transmission dynamics: reservoir-host-vector ecology and surveillance
- effects of climate change on chronic illness
- understanding the variability and distribution of vulnerability within the Victorian population
- health economics of impacts and adaptation
- evaluation of the effectiveness of adaptation strategies.

5. Conclusions

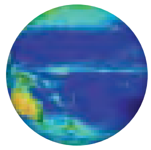
The health and wellbeing of human populations depend on the health of the ecological and biophysical life support systems of the planet. These systems are increasingly under threat from a number of environmental changes and climate change is perhaps the biggest we have ever had to face. No matter what technological solutions we may invent, we cannot escape the need to live within the limits of the Earth's resources.

A mix of adaptation and mitigation measures can reduce the risks associated with climate change. Unmitigated climate change would, in the long term, be likely to exceed the capacity of natural, managed and human systems to adapt.

We need to better research the relationship between climate and human health. We need to establish long-term data sets to give us better information with which to work. In studying climate change we face a number of challenges including the complexity of the interactions, the long period of time over which changes may occur, and the uncertainty in studying human populations.

We will have to adapt to more heatwaves and intense rainfall events, more frequent and severe droughts, fires and storms, and changes in the patterns of infectious diseases.

We need to better understand and assess vulnerability and identify and evaluate adaptation options.
The health of Victorians will increasingly depend on the effectiveness of our efforts to adapt to the many challenges of climate change.

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