Human Health Impacts of Climate Change for New Zealand

Evidence Summary

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Summary

Climate change is affecting New Zealand and the health of New Zealanders as many factors that contribute to our health and well-being are threatened by climate change. Over time, increasing climate change will lead to our health being impacted more severely, and more of us will be affected.

Direct effects from climate change include increased exposure to heat waves and weather events, flooding and fires.

Indirect environmental effects from climate change include increased exposure to microbial contamination, pollen, particulate air pollutants and carriers of new diseases.

Indirect social effects from climate change include disruption to health services, social and economic factors including migration, housing and livelihood stresses, food security, socioeconomic deprivation and health inequality.

The consequences of climate change are also expected to have adverse mental health and community health effects.

The effects of climate change will not be spread evenly across the population, exacerbating existing socioeconomic and ethnic health inequalities.

Well-designed policies to reduce global greenhouse gas emissions will not only limit climate change and reduce the associated risks to human health, but have the potential to improve population health and reduce health inequalities.

More research is needed to better quantify the health impacts of climate change for New Zealand in the short, medium and long term, particularly where impacts are indirect.

Building Blocks of Health Disrupted by Climate Change

Health impacts of climate change

Human health is affected by weather patterns and increased variability in temperatures. Many of the fundamental building blocks for health and well-being are threatened by climate change [1].

Changes in climate

In the Australasian region our climate is changing. There are long-term trends toward higher air and sea surface temperatures; increased frequency of extreme heat events; fewer events of extreme cold; and changes in rainfall patterns [2].

In New Zealand, if global greenhouse gas (i) emissions continue to rise at close to current rates, we can anticipate air temperatures to rise by another 2.5 °C to 5 °C by the end of this century, averaged across the country, and sea temperatures to rise by 3 °C [3, 4]. Further, annual average rainfall is expected to decrease by about 10% in the east and north of the country, with 'severe' droughts becoming several times more frequent in those areas [5]. Extreme heavy rainfall events are expected to become four times more frequent in most parts of the country. Sea-level rise is expected to accelerate, rising between 0.6 to 1.1 m by 2100, relative to 1986–2005 levels. Current '1 in 100-year' extreme sea level events, such as low pressure storm surges, are expected to occur once every year or so in many coastal regions [6]. The waters around New Zealand are already becoming less alkaline. Their pH is expected to decrease from 8.1 to 7.8 between 2005 and 2080–2100 [7] which because pH units are on a logarithmic scale, corresponds to a doubling of the concentration of hydrogen ions (H^+) in the ocean.

Impacts on human health

There is evidence that in recent decades climate change has contributed to increased levels of ill health, particularly in connection with summer heatwaves [1]. However, as the climate continues to change, the global health impacts are projected to increase, resulting in approximately 250,000 additional deaths globally per year by 2030 as a result of heat exposure, diarrhoeal disease, malaria and childhood undernutrition alone [8]. Reductions in global food availability, and fruit and vegetable consumption in particular, are estimated to result in a further 500,000 climate-related deaths worldwide by 2050, particularly affecting the populations of south and east Asia [9].

Climate change affects human health in a number of ways. The ideal healthy human has complete physical, mental and social well-being, and not merely the absence of disease or infirmity (ii). Changes to the climate can impact on these:

- Directly via air and sea temperature, flooding or storms;
- Indirectly due to changes to the environment and ecosystems; and
- Indirectly due to social and economic changes, such as migration stresses, health inequality and socioeconomic deprivation [6, 10, 11].

The fifth assessment report of the Intergovernmental Panel on Climate Change indicates that until mid-century, climate change around the globe will act mainly by exacerbating health problems that already exist, particularly among those with the weakest health protection services and with the least capacity to adapt [1]. Beyond this, major changes in ill health will occur through injury, disease and death from more intense heatwaves and fires; more flooding; undernutrition from diminished food production; increased food-, water- and insect-carried diseases; and lost work capacity and labour productivity [1].

The Asia and Pacific regions also have large numbers of people living in areas at risk of sea level rise. Inhabitants of low-lying coral atolls may expect increased contamination of freshwater reservoirs, flooding of settlements, and salt water contamination of soil, all of which can have important direct and indirect negative effects on health [1], [12].

(i) Climate change is largely attributable to emissions of carbon dioxide (CO_2) due to human activity. It is also driven by nitrous oxide (N_2O) and methane (CH_4). Other gases in the greenhouse gas family include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) that are used as refrigerants, solvents etc. Even though they have grown since 1990, these other gases remain of little significance in New Zealand (~2% of total emissions).

(ii) http://www.who.int/about/mission/en/

Levels of risk

The level of risk to human health associated with climate change will depend on the exposure of people, infrastructure, the environment and ecosystems to those hazards (e.g. geographical location), and their vulnerability to those hazards. Vulnerability includes sensitivity and susceptibility to harm as well as capacity to cope and adapt [6]. Age, education, income and livelihood type, housing type and quality, social networks and cultural relationships all contribute to resilience and vulnerability, and have been widely shown to influence how different groups can respond to climate-driven stresses and risks [13].

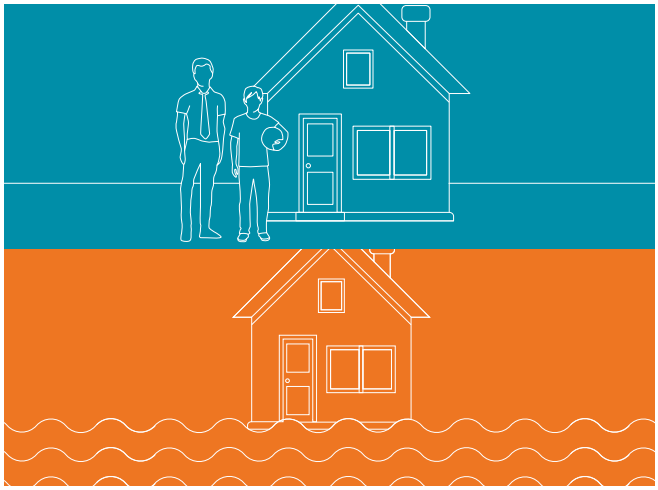
In New Zealand, children, the elderly, people with disabilities and chronic disease, and low-income groups are particularly vulnerable [14, 15]. Existing health inequalities (iii), having an economic base invested in primary industries, housing and economic inequalities , and a greater likelihood of having low-income housing in areas vulnerable to flooding and sea level rise, all make climate change a particular risk for Māori [10, 16, 17].

This update outlines the current research evidence for a number of potential human health impacts of climate change for New Zealand [10, 15, 18-20]. The adaptability and resilience of health and welfare systems are important factors in minimising the effects of climate change on human health [21]. However, there are significant gaps in the body of research quantifying the health impacts of climate change for New Zealand. This is particularly the case around the interactions of climate change, demographic change, and social change, which will increase people's vulnerability and exposure to climate risks.

Direct health impacts of climate change

Increased flooding, fires and infrastructure damage

Increased frequency of fires, floods, storm tides, and high intensity rainfall events will affect public health. Extreme events, such as the June 2015 flooding in South Dunedin [22] and the 2017 Edgecumbe floods and Christchurch fires [23, 24] pose immediate risks associated with being burnt by fire, or being swept away when driving or walking through floodwaters or landslides [25, 26].



We need adequate shelter for our health but some homes may become uninhabitable due to floods, erosion or fire.

These extreme events may also have negative effects on well-being through disease outbreaks, toxic chemical contamination, effects of damp buildings, mental health issues, disruption to healthcare access and damage to homes, which can last from weeks to months after the initial event [27-29].

Some Māori communities are also likely to be particularly vulnerable to increased flood risk due to climate change because of the location of valued infrastructure and sacred sites on exposed, erosion-prone coastal lands [30].

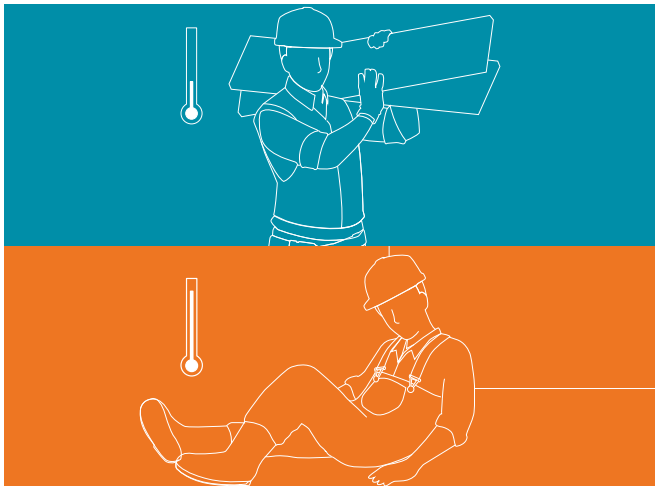
(iii) http://www.otago.ac.nz/wellington/departments/publichealth/research/hirp/otago020194.html#overview

Displacement

Strong social ties support our health but communities maybe disrupted if neighbourhoods are abandoned or relocated.

Sea level rise and coastal retreat require people to leave their homes. This can cause uncertainty for vulnerable populations and lead to mental health issues from the trauma of leaving familiar surroundings, the breaking of social ties, and the difficulty of resettlement [31, 32].

Extreme temperatures



Moderate temperatures make life and work comfortable but more hot days will increase heat stroke, aggression and heart disease, especially for outdoor workers.

Hot days (above average seasonal temperatures) have well-established negative impacts on the levels of illness and death [33]. Diabetes and cardiovascular disease increase sensitivity to heat stress [34, 35].

Key factors that can reduce or amplify health impacts include the magnitude and duration of the high temperatures and the speed of temperature rise. This is especially true when hot periods occur at the beginning of summer, before people have acclimatised to hotter weather [36]. Cities, with large impermeable surfaces, can also act as heat islands, increasing the temperature of hot days and retaining the heat at night [37].

If greenhouse gas emissions continue at close to current levels, many places in New Zealand will see more than 80 days per year above 25 °C by 2100, whereas currently most parts of the country typically see between 20 and 40 days per year above 25 °C [6]. For example, in Auckland and Christchurch, a total of 14 heat-related deaths occur per year amongst those people aged over 65 when temperatures exceed 20 °C. This is likely to rise to 28, 51 and 88 deaths per year for average global warming of 1, 2 and 3 °C above current temperature levels, respectively [38]. Elderly populations are especially vulnerable to heatwaves [39]. With around 1 in 4 New Zealanders projected to be 65 and over by 2043 (iv), the number of heat-related deaths is likely to be amplified.

Heat also poses significant risks to occupational health and labour productivity in areas where people work outdoors for many hours in susceptible regions [39, 40]. These risks, including heat stroke and renal impairment, have been documented in young and middle-aged men in France [41], agricultural workers in the USA [42], and sugar-cane harvesters in Central America [43]. In 2015, there were over 171,000 workers in agriculture, forestry and fishing in New Zealand (v).

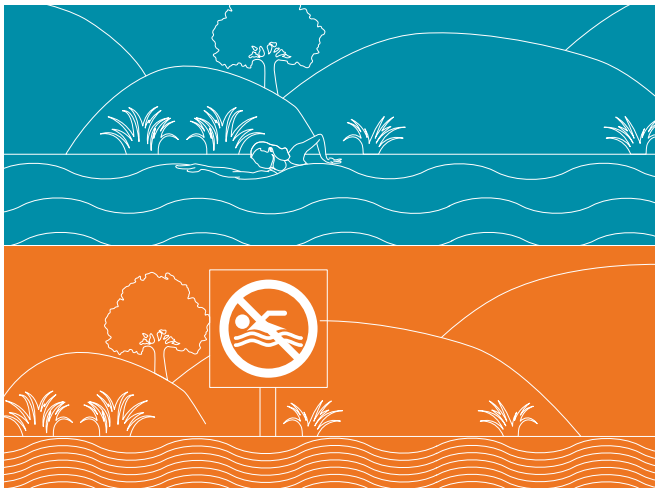
Increased heat is also associated with increased incidences of aggressive behaviour, violence and suicide. Hospital and emergency room admissions increase at temperatures above 18–20 °C for those with mental health or psychiatric conditions [44, 45]. Individuals with mental illness are especially vulnerable to high temperatures (e.g. 28 °C) or heat waves [46]. In six international case-control studies, pre-existing mental illness was found to triple the risk of death due to heat wave exposure, potentially through not drinking enough fluids, getting access to cool places, or recognising symptoms of heat exposure [47].

(iv) http://www.stats.govt.nz/browse_for_stats/population/estimates_and_projections/NationalPopulationProjections_HOTP2016.aspx

(v) http://www.stats.govt.nz/tools_and_services/nzdotstat/tables-by-subject/leed-annual-tables.aspx#1

Indirect health impacts of climate change

Harmful algal blooms



Clean water is essential for our health but droughts, floods and increased temperatures may lead to water contamination and toxic algal blooms.

Increasing temperatures will increase the likelihood of blooms of harmful algae, including blue-green algae (cyanobacteria). These algae produce toxins that can, by either contact or ingestion, cause liver damage, skin disorders, and gastrointestinal, respiratory and neurological symptoms [48]. These blooms can be widespread and long-lasting and have impacts on both commercial seafood harvesting and people reliant on non-commercial harvesting, particularly people of Māori and Pacific ethnicity [49, 50].

Freshwater

Blue-green algal blooms are strongly influenced by rising temperatures, altered rainfall patterns, and changes in the natural turnover and refreshing of water bodies [51, 52]. As average temperatures rise, the seasonal and geographic range of suitable habitat for blue-green algae species is projected to expand [53], with potential impacts on drinking water supplies and recreational water use. For example, heavy rainfall and subsequent run-off can increase nutrient loading in freshwater lakes and reservoirs, which in turn increases the likelihood of harmful blue-green algae blooms [54]. Low water levels caused by droughts also concentrate nutrient levels in lakes, and promote the growth of toxic blue-green algae living on the beds of rivers [55].

Marine

The projected impacts of climate change on toxic marine algae include changes to the geographic range of both warm- and cold-water species, changes in abundance and toxicity, and changes in the timing of the seasonal window of growth [56, 57]. For example, unusually warm water conditions in 1998 triggered widespread toxic blooms along the east coast of New Zealand (including Wellington Harbour) [58].

Toxic marine algae can contaminate New Zealand's shellfish [59]. The algae *Gambierdiscus* could cause Ciguatera fish poisoning, which results from people eating fish that have consumed toxins produced by the algae, if it was to become established [60]. This causes gastrointestinal upset followed by neurological conditions such as numbness, tingling or burning in the skin [60]. Globally, Ciguatera is the most frequently reported fish-related poisoning in humans and a significant health problem in the Pacific Islands [60]. The algae has been found occasionally in New Zealand, but rising sea temperatures and changing currents could lead to its permanent establishment in the seas surrounding the country [61].

Microbial contamination

Climate change is expected to affect fresh and marine water resources in ways that will increase people's exposure to waterborne diseases caused by bacteria, viruses and protozoa (vi) such as *Giardia* and *Cryptosporidium*.

Changing weather patterns, including more extreme rainfall events, flooding, and higher temperatures, are likely to interact with agricultural run-off, and affect the incidence of diseases transmitted through infectious drinking and recreational water. This can occur through contamination of drinking and recreational waters, as was seen with the *Campylobacter* outbreak in Havelock North in August 2016 [62]. It can also occur when conditions that are more suitable for bacterial growth are created [63, 64]:

- **In freshwater** – *Salmonella* and *E. coli* concentrations in streams can increase significantly in the summer months, and following heavy rainfall [65, 66]. The bacteria *Leptospira*, that is introduced into water from the urine of infected animals [67], can also cause increased human illness (ranging from nausea to renal failure) following increased temperatures and flooding events [68, 69].

(vi) Single-celled microscopic animals, which include amoebas, flagellates, ciliates, sporozoans and many other forms.

- **Drinking water** – internationally, and in New Zealand, extreme rainfall events have been linked to increased levels of harmful microorganisms. These include *Norovirus* [70], and those causing cryptosporidiosis and giardiasis diarrhoea in treated drinking water supplies [71, 72]. An increased incidence of gastrointestinal illness in children can follow [73]. This established relationship suggests that extreme rainfall can be a key climatic factor influencing the incidence of waterborne disease [74]. Small community or private groundwater wells, and other drinking water supplies where water is untreated or minimally treated, are especially susceptible to contamination following extreme precipitation events [75].
- **Marine waters** – the marine bacteria *Vibrio* can cause infected wounds, or diarrhoea or septicaemia if it contaminates sea food [76, 77]. *Vibrio* growth rates are highly responsive to rising sea surface temperatures, particularly in coastal waters [78]. Regional climate changes that affect coastal salinity (such as flooding, drought, and sea level rise) can also affect the relative abundance of different *Vibrio* species populations in marine waters [79, 80].

Although detailed research on the impacts of climate change on these risks for New Zealand still needs to be undertaken, New Zealand already has relatively high rates of waterborne illness compared with other high income countries [81], estimated at causing between 18,000 and 34,000 cases of gastroenteritis per year [82], with the largest single outbreak of waterborne illness affecting 5,500 people in 2016 [62]. While the World Health Organization has modelled the likelihood of additional childhood deaths in New Zealand due to all causes of diarrhoeal disease as a result of climate change by 2050 to be between an additional 1-3 deaths per year, the report highlights the significant impact of higher temperatures on increasing diarrhoeal disease transmission, and increasing risk of illness which could range from days off work to hospitalisation [8].

Food availability, quality and safety

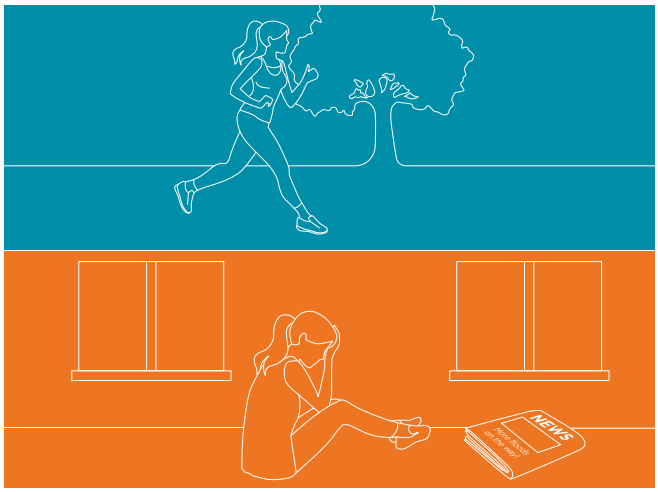
We need healthy food but droughts, floods and changes in weather patterns increase risk of crop disease, food spoilage, shortages and contamination.

Climate change-induced changes to weather patterns and sea-level rise have direct effects on food production, which can affect food availability and affordability, globally and locally [8, 9, 83]. In 2050, there are predicted to be an additional 140 climate-related deaths per annum in New Zealand as a result of changes in fruit, vegetable, and red meat consumption, and bodyweight-related risk factors (including coronary heart disease, stroke, and cancer) in the adult population [9].

Changes in air and water temperatures, rainfall patterns, and extreme events can also shift the seasonal and geographic occurrence of bacteria, viruses, parasites, fungi, and other pests and chemical contaminants [84-89]. This can lead to reduced food safety prior to, during and after the harvest, and during transport, storage, preparation and consumption. For example:

- Higher temperatures can increase the number of microorganisms already present on fruit and vegetables [90].
- Sea surface temperature is directly related to seafood exposure to microorganisms and biotoxins [91].
- Extreme events like flooding have been identified as a factor in the contamination of irrigation water and farm produce [87, 92, 93], and the *E.* coli contamination of shellfish [94].
- Changing environmental conditions and soil and water properties may lead to increased levels of heavy metals in the food supply [95]. For example, higher temperatures increase the rate of toxic methyl mercury formation by microorganisms in marine waters and sediments, with implications for elevated levels of mercury in fish [96, 97]. Fish are a significant source of mercury in the New Zealand diet [98].

Mental health and well-being



Mental outlook is important for health but repeated stresses from extreme weather and other impacts of climate change may take a toll on our well-being.

As mentioned above, increased temperatures, extreme weather events, and displacement of people from homes and communities will all have significant mental health and well-being consequences [99, 100]. These range from minimal stress and distress symptoms to clinical disorders such as anxiety, depression, post-traumatic stress and suicidal thoughts [101-103]. Other consequences include effects on everyday life, perceptions, and experiences of individuals and communities attempting to understand and respond appropriately to climate change and its implications [104].

Environmental change

Degradation of a familiar environment can cause distress [105]. Research in Australia during the decade-long drought which officially ended in 2012 revealed an increase in anxiety, depression, and possibly suicide in rural populations. In these communities, concerns about financial and work-related issues were compounded by loss of hope for the future and by a sense of powerlessness or lack of control [105, 106]. For New Zealanders, the natural environment is at the heart of the nation's identity, particularly for Māori, shaping the economy, lifestyles and culture [107]. Disruption of cherished bonds between individuals and their environment, such as during the managed retreat of threatened coastal communities [108], can cause grief, loss, and anxiety.

Threat of climate change as a stressor

Routine exposure to images, headlines, and risk messages about the threat of current and projected climate change provide a powerful and on-going stress-inducing aspect of an individual's everyday environment [109]. Between 2005 and 2016, there were on average 422 articles published per month mentioning climate change or global warming in print and online media in the New Zealand region, according to the global media database Factiva (vii). In the US, psychological responses to such stress have been shown to include heightened risk perceptions, general anxiety, pessimism, helplessness, eroded sense of self and collective control, stress, distress, sadness, loss, and guilt [109, 110].

Outdoor air quality

Clean air is vital for our health but changes in temperature and rainfall can increase air pollution and pollen allergens, which will increase the prevalence of respiratory problems.

Changes in temperature, rainfall and air stagnation (viii) affect air pollution levels with resulting risks to human health [111-113]. Chronic health conditions such as asthma and chronic obstructive pulmonary disease are particularly affected by outdoor air quality [34, 114, 115]. One in nine adults in New Zealand had asthma in 2013–2014 [116], and in 2005–2007 in New Zealand chronic obstructive pulmonary disease in those over 65 years of age was the third leading cause of death for women and fourth leading cause of death for men [117].

(vii) https://www.dowjones.com/products/factiva/

(viii) Air stagnation is a phenomenon which occurs when an air mass remains over an area for an extended period. Due to light winds and lack of precipitation, pollutants cannot be cleared from the air, either gaseous (like ozone) or particulate (like soot or dust).

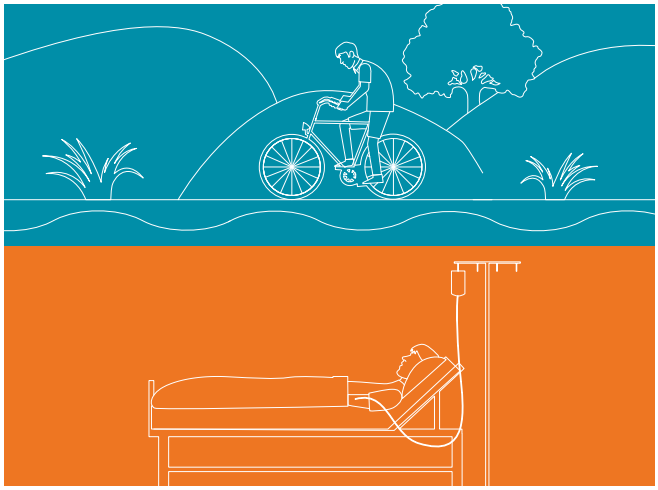
Particulate air pollutants

In 2012, exposure to human-made PM10 (particulate matter with a diameter of 10 micrometres (μm) or less) in New Zealand was estimated to have caused 1000 premature deaths, over 500 hospital admissions, and over a million restricted activity days [118]. Climate change is expected to increase seasonal fire severity in New Zealand, with greater changes in the east and north of the country [6]. These fire events can have important negative effects on human health through emissions of PM10 and PM2.5 and ozone [119]. Particulate matter smaller than 2.5 μm in diameter (PM2.5) is associated with serious chronic and acute health effects, including lung cancer, chronic obstructive pulmonary disease, cardiovascular disease, and asthma development and exacerbation [120-122]. Patients with underlying diseases, the elderly, and children are particularly sensitive to particulate exposure [122, 123]. The amount of soil-derived PM10 dust in the air may also increase in areas more frequently affected by drought. For example in Masterton, soil has been found to contribute up to 14% of the PM10 particulate matter in the air [124].

Pollen allergens

Climate change may contribute to changes in the incidence of allergic illnesses, such as asthma. Greater concentrations of CO_2, together with higher temperatures and changes in precipitation, extend the start or duration of the growing season, increase the quantity and allergic potential of pollen, and expand the spatial distribution of pollens [125-128]. In New Zealand, grasses form the main source of atmospheric pollen in spring and summer [128]. Historical trends show that climate change has already led to changes in the length of the growing season for certain plant species that are sources of allergenic pollens [129]. Studies also find that increases in CO_2 levels result in greater pollen production and increased allergic potential of grass [127] and pine trees [130]. Annual birch pollen production in 2020 and 2100 is projected to be 1.3 and 8 times higher respectively, relative to average values for 2000, with the start and peak dates of pollen release becoming earlier by two to four weeks [131].

Carriers of new diseases



Avoiding disease is vital for our health but rates of infection are likely to increase. Tropical diseases like malaria or West Nile virus may establish in New Zealand.

There are a number of organisms, including mosquitoes, ticks, and fleas that can transmit infectious diseases between humans or from animals to humans. The seasonality, distribution, and common occurrence of diseases spread by these carriers are largely influenced by climatic factors, and in particular by high and low temperature extremes, and precipitation patterns [132]. These factors can affect disease outbreaks by changing the population size, population density, and survival rates of the disease carriers. In addition, climate change may affect the relative abundance of other animals that are part of the disease cycle, and higher temperatures can increase the infectious agent's own reproduction rates [133]. Collectively, these changes may contribute to an increase in the risk of the infectious diseases being transmitted to humans in some areas [134].

Climate change also heightens the risks for New Zealand associated with a number of mosquito-borne and tick-borne diseases, currently absent from New Zealand. These include West Nile virus [135, 136], dengue fever [137], Murray Valley encephalitis [138], Japanese encephalitis [139], Ross River virus [140], and Barmah Forest virus [141], most of which are present in Australia. Importantly, there are emerging pathogens that have recently spread worldwide (such as chikungunya and Zika viruses), which are already present in the Pacific Islands and which could become more of a risk in New Zealand if climate change allows important disease-transmitting mosquitos to become established here [142-145].

Changes to mosquito distribution

There are currently no mosquito species in New Zealand capable of transmitting malaria [146]. In addition, some of the most important mosquito species that carry human disease worldwide, in particular *Aedes aegypti* and *Aedes albopictus*, are not present in New Zealand [144]. However, mosquitoes are regularly intercepted in New Zealand [147], and these species would be more likely to establish in this country under rising temperatures and with changes in precipitation patterns [148]. This would result in New Zealand having an increased risk from mosquito-borne diseases, such as dengue and Ross River viruses, which regularly arrive in the country with infected travellers [149, 150]. Extreme weather events, such as drought followed by rewetting, can also increase mosquito populations by changing water table levels, vegetation, and populations of aquatic predators. These links between climate change, mosquito populations, and the life-cycle of diseases are likely to increase the range and incidence of diseases such as malaria [151] and dengue fever [152], which may become significant in areas where temperature is currently the limiting factor [153].

Other parasitic diseases

There are a number of parasitic diseases that are characteristic of warmer climates, which do not occur in New Zealand, but which could become established in the country as a result of climate change. For example, the establishment of flies whose larvae infest skin [154] or of lung fluke-carrying snails [155].

Migration of tropical species into New Zealand

The waters around New Zealand are warming as the overlying atmosphere warms [6]. Tropical species such as the green turtle are now increasingly being seen in northern New Zealand waters [156]. Harmful species such as sea snakes or toxic jellyfish may similarly extend their ranges to New Zealand. Similarly, the warming and drying of some areas of New Zealand may make these areas more suitable for the establishment of poisonous species such as the invasive Australian redback spider [157].

Potential health benefits

Reduced cold mortality

For the cooler areas of New Zealand, rising temperatures might reduce cold-related illness and deaths. In New Zealand, around 1600 more winter deaths occur each year compared with the summer, with winter mortality rates from all causes (including those only indirectly related to temperature), being 18% higher than non-winter rates [158, 159]. It is unclear, however, how many of the deaths that occur at colder times of the year are due to low temperatures, rather than other phenomena that vary with season. This means it is difficult to establish how much reduction in death rates there might be in warmer winters [160, 161].

Health impacts from mitigating climate change

Climate change mitigation measures can result in a number of health-related co-benefits in the short term [162]. Reductions in fossil fuel use in transport, domestic heating, and electricity generation, in addition to reducing CO_2 emissions, will reduce the release of fine particle air pollution (PM10) responsible for increased risk of respiratory disease [18, 163], cardiovascular disease [111], and potential risk of premature births [164]. For example, in the transport sector In New Zealand, it is estimated that a 5% shift in light vehicle kilometres travelled for short journeys to cycling would annually save around 50,000 tonnes of CO_2. In addition, there could be 116 fewer deaths per annum as a result of the benefits of physical activity, and 5.6 fewer deaths from vehicle emissions [165].

Similarly, an assessment of the effect of retrofitting houses in New Zealand with insulation suggested there could be savings of 217 kg of CO_2 per household per year through improved energy efficiency. At the same time there would be reductions in the number of inpatient hospital respiratory admissions for the elderly, days off school for school age children, and days off work for adults [166].

The way policy is enacted can also impact on health outcomes. For example, mitigation measures to reduce energy use in buildings could lead to lower air ventilation rates resulting in higher concentrations and exposures to indoor pollutants [167].

For further information

For more information and resources about the implications of climate change for New Zealand, and possible mitigation options for New Zealand, visit the Society's web site: http://www.royalsociety.org.nz/climate

This paper was authored by the Royal Society Te Apārangi, under the guidance of the following expert reference group: Dr Annette Bolton, Dr Alison Dewes, Brian Dixon, Professor Nigel French FRSNZ, Emeritus Professor Frank Griffin FRSNZ, Dr Alex Macmillan, Professor James Renwick, and Professor Ian Shaw.

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For further information, please contact info@royalsociety.org.nz.

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