Environmental Health Indicators: development of a tool to assess and monitor the impacts of climate change on human health

Health Analysis & Information For Action (HAIFA)

Tammy Hambling

ISBN 978-1-877166-20-4 September 2012




Acknowledgements

This report could not have been produced without the ongoing support and guidance of David Slaney for both the Health Analysis and Information For Action (HAIFA) research project and his MPhil supervision.

The author would like to thank David Slaney, Graham Mackereth and Bronwyn Morris for their review of the draft report and the helpful feedback they provided.

This work was funded by the New Zealand Foundation for Research, Science and Technology and the Ministry of Science and Innovation (contract C03X0801).

Front cover images:
New Zealand and cyclone images are sourced from http://www.nasa.gov.
The drought, flood and crowd images are sourced from http://www.istockphoto.com.

Disclaimer

This report or document ("the Report") was prepared by the Institute of Environmental Science and Research Limited ("ESR") for the benefit of ESR. Neither ESR nor any of its employees makes any warranty, express or implied, or assumes any legal liability or responsibility for use of the Report or its contents by any other person or organisation.

ISBN 978-1-877166-20-4 (PDF)

Published by
Environmental Science and Research Limited
P O Box 50-348
Porirua 5240
New Zealand

http://www.esr.cri.nz

Table of Contents

List of Tables

List of Figures

1. Aim

To develop a core set of environmental health indicators (EHIs) to assess, quantify, and monitor the impacts of climate variation and change on food- and water- borne diseases in New Zealand. In particular, this report focuses on salmonellosis and cryptosporidiosis.

2. Purpose of the report

The primary purpose of this report is to describe the methods used to select and develop a core set of EHIs to explore the relationships between and impacts of climate variation and change on food- and water-borne diseases in New Zealand. In particular, this report focuses on salmonellosis and cryptosporidiosis and presents working examples of EHIs for salmonellosis.

In addition, the report seeks to:

- Illustrate how EHIs can be used as a tool to aid environmental health decision-making, by forming a basis for describing and better understanding the environmental health causal chain/networks for climate variation and change, and food- and water- borne diseases.
- Provide a resource for discussion about how to reduce the burden of disease from environmentally driven health issues by identifying and developing measures to assess, quantify and monitor human health vulnerability, informing the design and targeting of interventions, and measuring the effectiveness of adaptation and mitigation activities.
- Encourage a multidisciplinary approach to link existing environmental and epidemiological data and networks. Analysis of such data will contribute to an enhanced understanding of the relationships between climate change and human health.

In this report, the analyses and results presented in the example EHIs for salmonellois are descriptive only and do not fully examine the causal relationship between driving forces, pressures and the state of the environment and human health outcomes. This report will be updated in 2013 with the incorporation of results from a bayesian network analysis approach.

In addition to forming a module within the Health Analysis and Information For Action (HAIFA) project, the content of this report forms part of Tammy Hambling's MPhil thesis that will be submitted in 2013. The thesis will incorporate additional information, analyses, and interpretation of a number of EHIs including those presented in this report. Once the MPhil is confirmed, this additional work will be available in the thesis and associated publications.

3. Introduction

New threats to human health, particularly the emergence and spread of diseases, are becoming major issues associated with components of global environmental change (Confalonieri & McMichael 2006; Jones *et al.* 2008; Leisnham & Slaney 2009). Contributing to these human health threats are the roles that climate variability and change, and extreme weather events, play in altering disease risk (Aron & Patz 2001; Ebi *et al.* 2005; Hennessy *et al.* 2007; Patz *et al.* 2005). The roles of climate variability and change are important as the processes will compound the already significant burden of infectious diseases (eg, vector-, food- and water- borne disease) on national economies and public health. Therefore, authorities need to be able to assess, anticipate, and monitor human health vulnerability to climate variability and change, in order to plan for, or implement action to avoid or reduce negative consequences.

Environmental health indicators provide information about a scientifically based linkage between the environment and health, enabling the conversion of data to information by summarising these complex relationships and presenting them in a form that is more easily interpreted by the end-user (eg, policy makers) (Briggs 2003; Hambling *et al.* 2011; Kjellström & Corvalán 1995). Therefore, EHIs can be used as a tool to assess, quantify and monitor ecosystem health vulnerability from a sustainability perspective and can be utilised to inform adaptations and policy development and measure the effectiveness of climate change adaptation and mitigation activities. In addition, they provide baseline information for assessing and monitoring temporal and spatial variability of risks with respect to climate change, enabling projection scenarios (eg, epidemics, cost/benefits of interventions) of how the current situation may evolve. Monitoring of human disease surveillance data has the potential to act as a warning system for ecosystem disruption and may be used to identify interventions for the preservation of ecologic and human health. Such an approach means that interventions can be applied higher up the causal chain than would have been possible based on environmental monitoring or health surveillance alone. Implementation of such interventions can improve ecological well-being which in turn will reduce the resultant burden of disease in humans.

The Driving force-Pressure-State-Exposure-Effect-Action (DPSEEA) framework is used to develop and structure the EHIs covering each component of the DPSEEA framework to describe the causal chain/network for the selected environmental health issue of concern (Figure 1). This framework provides a systematic approach that aids interpretation of complex environmental health issues by demonstrating links or relationships between the environment and human health (Hambling *et al.* 2011).

4. Methods and Results

4.1 Framework selection

Given the complexity of environmental health issues, it is important to use a systematic structured framework to select and develop a relevant range of EHIs and to enable consistent monitoring and interpretation. A framework provides a systematic approach that aids interpretation of complex environmental health issues by demonstrating links or relationships between the environment and human health. Frameworks can also help ensure the selection of a relevant and balanced range of EHIs and help to recognise and interpret complicated links between them (Briggs 2003). Various frameworks have been designed for developing indicators and assessing vulnerability, and the framework's suitability will vary depending on the issue of concern.

4.1.1 Selection process

Using the published literature we reviewed the attributes of 11 frameworks to identify the most suitable framework for developing EHIs to measure and monitor the impacts of climate change on human health and inform the development of interventions (Hambling *et al.* 2011). This included frameworks that had environmental and health components, or were indicator-based and had environmental components, but we did not evaluate the utility of indicator-based tools beyond EHIs.

List of frameworks evaluated:

- Pressure-State-Response
- Driving force-State-Response
- Driving force-Pressure-State-Impact-Response
- Burden of Disease
- Millennium Ecosystem Assessment
- Causal Web
- Driving force-Pressure-State-Exposure-Effect-Action
- Multiple Exposure-Multiple Effect
- Environmental Public Health Indicators
- Health Impact Assessment
- Integrated Environmental Health Impact Assessment

For more detailed information on the review of frameworks refer to Hambling *et al.* (2011).

4.1.2 Selection results

The Driving force-Pressure-State-Exposure-Effect-Action (DPSEEA) framework was identified as the best suited for developing EHIs for climate change and human health.

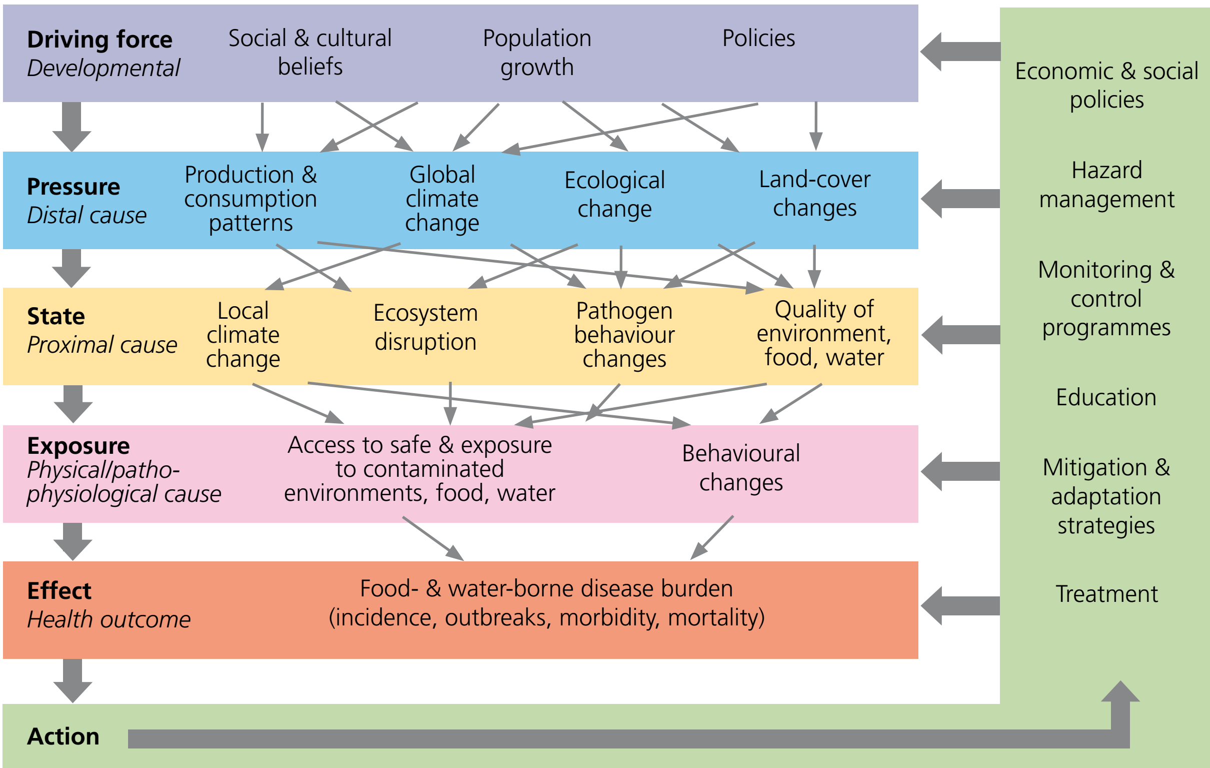
Driving force-Pressure-State-Exposure-Effect-Action framework

The DPSEEA framework was designed to support decision making on actions to reduce the burden of disease by describing environmental health problems from their root causes through to their health effects, and by identifying areas for intervention. It is a hierarchical approach that links measurable indicators to environmentally caused diseases, and displays the various levels of action that can be undertaken to reduce environmental health impacts (Figure 1). Analytical EHIs that quantify the impact at each step along the causal chain are particularly useful as they highlight where the most effective interventions can be aimed for protecting human health.

FIGURE 1: DRIVING FORCE-PRESSURE-STATE-EXPOSURE-EFFECT-ACTION FRAMEWORK APPLIED TO CLIMATE CHANGE AND FOOD- AND WATER- BORNE DISEASES

Adapted from World Health Organization (2001) & Hambling & Slaney (2007)

Note: to avoid cluttering the diagram not all possible interconnections have been depicted.



The DPSEEA framework describes six components of the environmental health causal chain. Each of the components is described below (Briggs 1999; Briggs 2003):

Driving forces: refer to the factors that motivate and push environmental processes (eg, anthropogenic and socioeconomic activities). They act as root causes for, and influences upon the processes of concern. Population growth is possibly the most important, while others include technology and economic development and policy interventions.

Pressures (on the environment): driving forces result in the generation of pressures on the environment thereby affecting the quality of the environment. These pressures are often expressed through human occupation or exploitation of the environment, and may be generated by all sectors of economic activity, including energy production, manufacturing, mining, agriculture, forestry, transport and tourism. Pressures arise in all stages of the supply chain from resource extraction, to processing, to consumption and waste release.

State: as a consequence of pressure the 'state' of the environment is changed. These changes may be complex and far-reaching, affecting almost all aspects of the environment. They can be expressed in the following ways, frequency or magnitude of natural hazards, availability and quality of natural resources and levels of pollution. Changes in the state of the environment can be intense and localised, often concentrated close to the source of the pressure (eg, habitat loss, air pollution, contamination of water supplies) or more widespread, contributing to regional and global environmental change (eg, climate change, desertification). All have far-reaching secondary effects due to the complex interactions that characterise the environment.

Exposures (of humans): refers to the intersection between people and the environmental hazard, occurring when humans are exposed to changes in environmental conditions. In the case of environmental pollution exposure can occur in a number of different ways, by inhalation, ingestion or dermal absorption, and may involve a range of different organs. External exposure is the quantity of the pollutant at the interface between the environment and the recipient. It is often measured by a form of personal monitoring or by modeling techniques.

Effects (health effects in humans): adverse impacts on health due to exposures to environmental hazards. They may vary in type, intensity and magnitude depending on the type of hazard, level of exposure and number of people involved. Effects can vary from sub-clinical, to a reduction in function or wellbeing, to illness or morbidity, to death (Briggs 1999). Links between the environment and health are often complex with individual hazards often leading to a wide range of health effects, while single health effects may derive from many different exposures and underlying causes.

Actions: are policy and other interventions, aimed at reducing or avoiding the adverse health effects. Actions can be targeted at any component of the DPSEEA framework.

For each environmental health issues of concern EHIs are developed (where possible) for each component of the DPSEEA framework to describe the environmental health causal chain/network.

4.2 Food- and water- borne diseases selection

Food- and water- borne diseases constitute the greatest burden of disease in New Zealand, with a number of these diseases having significantly higher rates than those in other developed countries. Thus, food- and water- borne diseases were chosen for developing climate change EHIs.

4.2.1 Selection process

Food- and water- borne diseases were identified from the list of diseases currently notifiable in New Zealand under the Health Act 1956 (Ministry of Health 2009). For each disease the total number of notifications in 2009 (latest year of data available at time of disease selection process) were extracted from EpiSurv, the national notifiable disease surveillance system. The following diseases were removed and not considered further:

- any disease considered to be imported or vaccine preventable (eg, Cholera, Hepatitis A, Typhoid, paratyphoid); and
- any disease with less than 10 notified cases in 2009 (eg, Ciguatera fish poisoning, Histamine (scromboid) poisoning).

Resulting list of diseases (in order of number of notifications):

- Campylobacteriosis
- Giardiasis
- Salmonellosis
- Cryptosporidiosis
- Yersiniosis
- Norovirus
- Verotoxin- or Shiga toxin- producing *Escherichia coli*

- Shigellosis
- Rotavirus
- Leptospirosis
- Legionellosis
- Listeriosis

For each disease in the list above a brief literature review was carried out to identify transmission routes and evidence for an association with climate variables. Following this each disease was assessed and ranked against the following:

1. New Zealand disease burden: total number of cases (confirmed and probable) notified in 2009;
2. Transmission route(s): primary route was identified where possible (faecal-oral, person-to-person, animal-to-person, air-borne, food-borne, and water-borne (drinking or recreational));
3. Correlation with climate variables: climate variable was identified where possible (seasonality, temperature, humidity, rainfall, and flooding);
4. Wider HAIFA project disease ranking scores (see the HAIFA modelling report available from the HAIFA web site) applied to the 12 diseases:
    1. Salmonellosis
    2. Campylobacteriosis
    3. Giardiasis and Shigellosis
    4. Cryptosporidiosis
    5. Yersiniosis
    6. Norovirus and Verotoxin- or Shiga toxin- producing *Escherichia coli*
    7. Legionellosis
    8. Listeriosis
    9. Rotavirus and Leptospirosis;
5. World Health Organization Europe - Climate, Environment and Health Action Plan and Information System (World Health Organization 2010): this project identified salmonellosis and cryptosporidiosis as core indicator diseases for food- and water- borne diseases to develop EHIs to assess and monitor climate-related health effects.

4.2.2 Selection results

Based on the assessment and selection process above and with the aim to cover a combination of transmission routes (ie, both food- and water- borne transmission pathways) two diseases (salmonellosis and cryptosporidiosis) were chosen as case studies for developing a core set of EHIs.

Salmonellosis

- Third most commonly notified food- or water- borne disease in 2009 (1129 notifications, rate of 26.2 notifications per 100,000 population)
- Primarily food-borne transmission route
- Strong climate/temperature link in literature
- Ranked first in HAIFA project ranking
- World Health Organization selected

Cryptosporidiosis

- Fourth most commonly reported food- or water- borne disease in 2009 (854 notifications, rate of 19.8 notifications per 100,000 population)
- Primarily water-borne transmission route
- Climate/temperature/rainfall link in literature
- Ranked fourth and selected for HAIFA project
- World Health Organization selected

4.3 Environmental health indicator selection

The development of good EHIs is challenging because they must satisfy multiple criteria to be effective. Several sets of criteria have been developed for EHIs with the following general criteria commonly agreed on. Environmental health indicators should (Briggs 2003):

- be scientifically valid or credible
- have clear relevance and utility
- be practical

More specific criteria include that EHIs must (Briggs 1999):

- provide a relevant and meaningful summary of the conditions of interest in a way that meets the requirements of the end-users (who are often not experts in the subject)
- be transparent, testable, scientifically sound, robust and sensitive to real changes in the conditions they measure
- utilise routinely collected data
- be cost-effective to apply and produce

Environmental health indicators will also provide baseline information for assessing and monitoring temporal and spatial variability of risks, enabling projections of how the situation may evolve.

Climate change EHIs are specifically aimed at monitoring the effects of climate change on health (Hambling *et al.* 2011). They can be defined as "an expression of the link between climate change and health, targeted to a specific policy or management concern and presented in a form, which facilitates interpretation for effective decision-making" (adapted from Corvalán *et al.* 1996, cited in World Health Organization 2001).

A climate change EHI is based on a known relationship between climate, an environmental exposure, and health. They have an important temporal component as they are used to detect change over time, therefore, data collected over long time periods are required. It is important to observe retrospective data, if possible, and to define a baseline, against which to measure change that is attributable to global climate change (World Health Organization 2001).

An information system derived from climate change EHIs should provide a comprehensive picture of important environmental health issues related to climate change that are of concern now and will continue to be so in the future. From a public health perspective, environmental health issues selected for developing climate change EHIs should cover diseases and conditions that represent an important health burden (in terms of magnitude and severity) but are largely preventable through active interventions aimed at reducing population exposure to the environmental health risks (World Health Organization 2010).

4.3.1 Selection criteria

Climate change EHIs need to be both scientifically valid and politically relevant, therefore they should be (Briggs 2003; Corvalán *et al.* 2000; World Health Organization 2001):

1. Credible (scientifically sound) – based on a known linkage between climate, an environmental exposure (not in all cases) and health
2. Specific – related (directly or indirectly) to a specific issue of climate change and health concern
3. Actionable – related to climate/environmental/health conditions that are amenable to adaptive actions
4. Sensitive to changes in climate and less sensitive to alternative (non-climate) explanations
5. Relevant to an issue of policy or practical concern
6. Sustainable – able to provide data for the next 20 to 30 years
7. Consistent and comparable over time and space
8. Scalable – capable of being used at different scales
9. Robust and unaffected by minor changes in methodology, scale or data used in their construction
10. Unbiased and representative of the conditions and area of concern

11. Explicit – identify specific adaptation responses
12. Accurate – based on data of a known and acceptable quality
13. Understandable, applicable, and acceptable to stakeholders and potential users
14. Measurable – based on available data and manageable methods with retrospective data available to provide a baseline, against which change can be measured
15. Cost-effective – capable of being constructed and used at an acceptable cost-benefit ratio
16. Selective – in that they help to prioritise key issues in need of action
17. Available in a timely manner.

Whilst it is recognised that few indicators can fulfil all of these criteria, the first four are considered to be the most important. All indicators need to fit the purpose for which they are intended. The criteria, like the indicators, are dependent on the situation in which they are used. Therefore, weighting given to specific criteria may vary between indicators depending on their intended purpose (Briggs 2003).

4.3.2 Selection process

After identifying the components and links that are needed to describe the causal chain/network for an environmental health issue a provisional list of possible indicators can be developed. This provisional list is then assessed for scientific validity, policy relevance and data availability.

In depth literature reviews were carried out on the priority diseases (salmonellosis and cryptosporidiosis, selected above in Section 4.2.2) to identify and map possible causal pathways/networks and to develop a provisional list of EHIs covering the DPSEEA chain for of the each diseases.

A provisional list of over 50 possible climate change EHIs was developed for salmonellosis and cryptosporidiosis.

Each possible climate change EHI was then individually evaluated for its fulfilment of the first four scientific validity and policy relevance criteria above (Section 4.3.1), as well as the following criteria for data availability in New Zealand:

1. Availability of data: current (latest year available), retrospective (a minimum period of 5 to 10 years was considered necessary, however, the longer the time period the better) and ongoing data;
2. Geographic scale and coverage (national, regional, local) and collection method (census, sample, sentinel etc);
3. Regularity of collection (monthly, annual, bi-annual, five-yearly, one-off survey etc); and
4. Reliability and consistency, evaluating the data quality is often difficult as the determinants of data quality such as validity, reliability and consistency are often not well documented and are hard to measure (Briggs 1999).

Each possible climate change EHI was then given a score out of four according to their fulfillment of the four scientific validity and policy relevance criteria and the four data availability criteria (ie, one point for each criteria).

From this a short list was created by:

1. Removing EHIs with a score of two or less for either the scientific validity and policy relevance or data criteria;
2. Ranking the remaining EHIs (within each DPSEEA component) by their combined score for both scientific validity and policy relevance or data criteria; and
3. Assessing the remaining list for gaps or potential duplicates. Assessing the indicator list for gaps and duplicates requires the list of indicators to be considered holistically and in context rather than as individual indicators (Briggs 2003).

Following this process a total of 19 climate change EHIs were proposed for full development; 15 for salmonellosis and 13 for cryptosporidiosis (Table 1; Table 2). Some climate change EHIs, particularly the high level (driving force and pressure) EHIs are common to both diseases while others are specific to a disease.

It should be noted that following the selection process some gaps are evident in the causal pathways/networks with some logical climate change EHIs not satisfying the selection criteria. The most common reason for not meeting the selection criteria was a lack of data availability. For example, for salmonellosis, no food-borne pathogen exposure (Exposure) indicators qualified for the final EHI short list.

4.3.3 Selection results

TABLE 1: PROPOSED CORE SET OF ENVIRONMENTAL HEALTH INDICATORS FOR SALMONELLOSIS

DPSEEA component	Name	Definition
Driving force	Population growth	Population estimates by geographic area (territorial authority)
Pressure	Energy consumption	Annual energy consumption by fuel type and sector for New Zealand
	Greenhouse gas emissions	Total greenhouse gas emissions for New Zealand
		Greenhouse gas emissions from animals (by type) and fertiliser for New Zealand
	Landcover types	Landcover types by geographic area (territorial authority)
	Livestock numbers	Number of livestock (by type) by geographic area (regional council)
	Climate	Mean monthly ambient temperature by geographical area (territorial authority)
		Total and mean monthly rainfall by geographical area (territorial authority)
State	Pathogen behaviour	*Salmonella* serotypes identified in New Zealand
	Drinking water quality – bacterial compliance	Proportion of registered drinking water supplies in each grade by geographic area (territorial authority)
	Recreational water quality	Proportion of recreational water sites (coastal and fresh) in each grade by geographic area (territorial authority)
	Food quality	Proportion of meat samples (taken during the production chain) with *Salmonella* isolated by meat type for New Zealand (data availability pending)
Exposure	Drinking water quality – population exposure	Proportion of the population on registered drinking water supplies that are exposed to each grade by geographic area (territorial authority)
Effect	Salmonellosis burden of disease	Salmonellosis notification rate by geographic area (territorial authority)
		Number of notified outbreaks and associated cases of salmonellosis by geographic area (territorial authority)
Action	Policies	EHI informed adaptations and policy development

TABLE 2: PROPOSED CORE SET OF ENVIRONMENTAL HEALTH INDICATORS FOR CRYPTOSPORIDIOSIS

DPSEEA component	Name	Definition
Driving force	Population growth	Population estimates by geographic area (territorial authority)
Pressure	Energy consumption	Annual energy consumption by fuel type and sector for New Zealand
	Greenhouse gas emissions	Total greenhouse gas emissions for New Zealand
		Greenhouse gas emissions from animals (by type) and fertiliser for New Zealand
	Landcover types	Landcover types by geographic area (territorial authority)
	Livestock numbers	Number of livestock (by type by geographic area (regional council)
	Climate	Mean monthly ambient temperature by geographical area (territorial authority)
		Total and mean monthly rainfall by geographical area (territorial authority)
State	Drinking water quality – protozoal compliance	Proportion of registered drinking water supplies that comply with the protozoan requirements of the DWSNZ by geographic area (territorial authority)
	Recreational water quality	Proportion of recreational water sites (coastal and fresh) in each grade by geographic area (territorial authority)
Exposure	Drinking water quality – population exposure	Proportion of the population on registered drinking water supplies that comply with the protozoan requirements of the DWSNZ by geographic area (territorial authority)
Effect	Cryptosporidiosis burden of disease	Cryptosporidiosis notification rate by geographic area (territorial authority)
		Number of notified outbreaks and associated cases of Cryptosporidiosis by geographic area (territorial authority)
Action	Policies	EHI informed adaptations and policy development

4.4 Environmental health indicator development – examples for salmonellosis

In this section working examples of EHIs for salmonellosis are provided. The EHIs included here are a subset of those listed in Table 1. The analyses and results presented here are descriptive only and do not fully examine the causal relationship between driving forces, pressures and the state of the environment and human health outcomes. Further analyses including a bayesian network analysis are being undertaken and will be incorporated in future reports.

4.4.1 Population growth

DPSEEA component: Driving force

Definition: Population estimates by geographic area (territorial authority)

Relevance and interpretation:

Population growth represents one of the major driving forces acting on environmental health. Rapid population growth may be seen as evidence of growing pressures on the environment and health-related services, and potential increased risks to health. Environmental damage and increased pressures on local infrastructure and services can results from rapid or persistent population growth. This can result in an increase in risk to health, for example, through inadequate nutrition, poor sanitation, insufficient access to safe drinking water, poor housing conditions and increased exposure to diseases (Briggs 1999). Understanding the complex ways in which population dynamics and environment affect each other requires consideration of such things as consumption, technology, socio-economics, and population growth patterns (eg, urbanisation). Population size represents one important variable in this complex relationship; other dynamics include population densities, distribution and composition (Hunter 2000).

Population growth is a significant factor driving climate change primarily through human-induced increases in the concentrations of greenhouse gases in the atmosphere (burning fossil fuels, deforestation, etc), which absorb solar radiation and warm the atmosphere. One estimate is that population growth will account for 35% of the global increase in carbon dioxide emissions between 1985 and 2100 (Bongaarts 1992). Population has a dual contribution to increased greenhouse gas emissions through growth in population numbers and per capita energy and materials consumption.

In New Zealand, under medium assumptions (medium fertility, medium mortality and long-term annual net migration of 10,000), the population is projected to grow by 24% from 4.06 million in 2004 to 5.05 million in 2051 (Statistics New Zealand 2004).

Further downstream effects of population growth and climate change include ecosystem degradation, resource scarcity, and migration pressures further straining limited natural resources, and increasing population density.

This indicator provides a useful measure of potential pressure on the environment and human health. It can be used, for example to:

- provide and early warning of developing pressures on the environment or service facilities
- identify areas of high population growth, as a basis for informing resource allocations
- help interpret patterns or trends in other environmental health indicators.

However, this relationship is complex and may not always be a valid indicator of potential pressures. The effects of population growth in an area may vary, for example:

- depending on the resource base of the area
- the lifestyle of the population
- the level of economic development
- level of trade with other areas
- the degree of development of its infrastructure and services
- the strength and adequacy of environmental and health planning.

There may be marked geographic differences in the population growth rate within the defined geographic areas that may be masked when data are aggregated to larger areas or when data is not available on a finer scale. Therefore this indicator should be interpreted with caution.

Computation: $(P_{t1} - P_{t0})/P_{t0}$ *100
Where P_{t1} = the total population at time 1
P_{t0} = the total population at time 0

Data source: Resident population estimates, Statistics New Zealand http://www.stats.govt.nz/

Results:

Temporal and spatial trends, 2001 to 2010

- Between 2001 and 2010, there was a steady increase in the population of New Zealand, with an overall increase of 12.6%. Similar increases were seen in both the North and South Islands (Table 3; Figure 2).
- The majority (79.5%) of territorial authorities showed an increase in population, however there were marked geographical differences (Figure 3).
- Territorial authorities that showed the largest increase in population were (Table 3; Figure 3):
  - Queenstown-Lakes (55.7%)
  - Selwyn (39.9%)
  - Rodney (27.4%)
- Territorial authorities that showed the largest decrease in population were (Table 3; Figure 3):
  - Ruapehu (-9.7%)
  - Wairoa (-8.9%)
  - South Waikato (-5.4%)

FIGURE 2: POPULATION ESTIMATES BY AREA, 2001 TO 2010

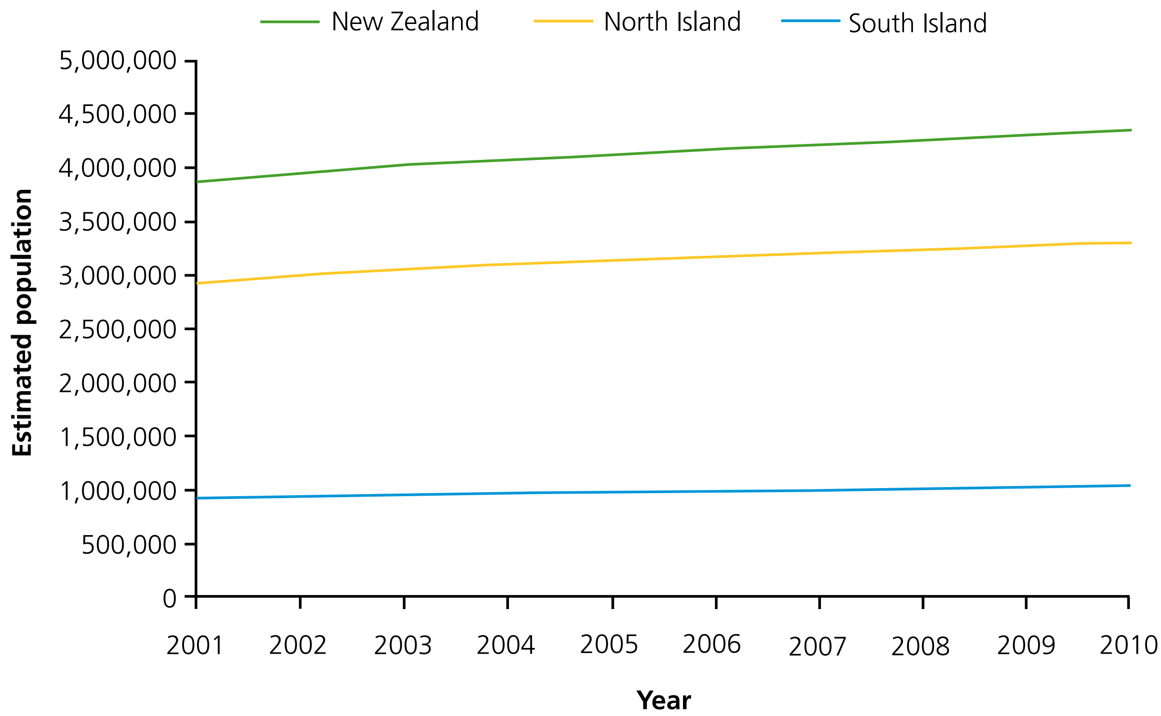
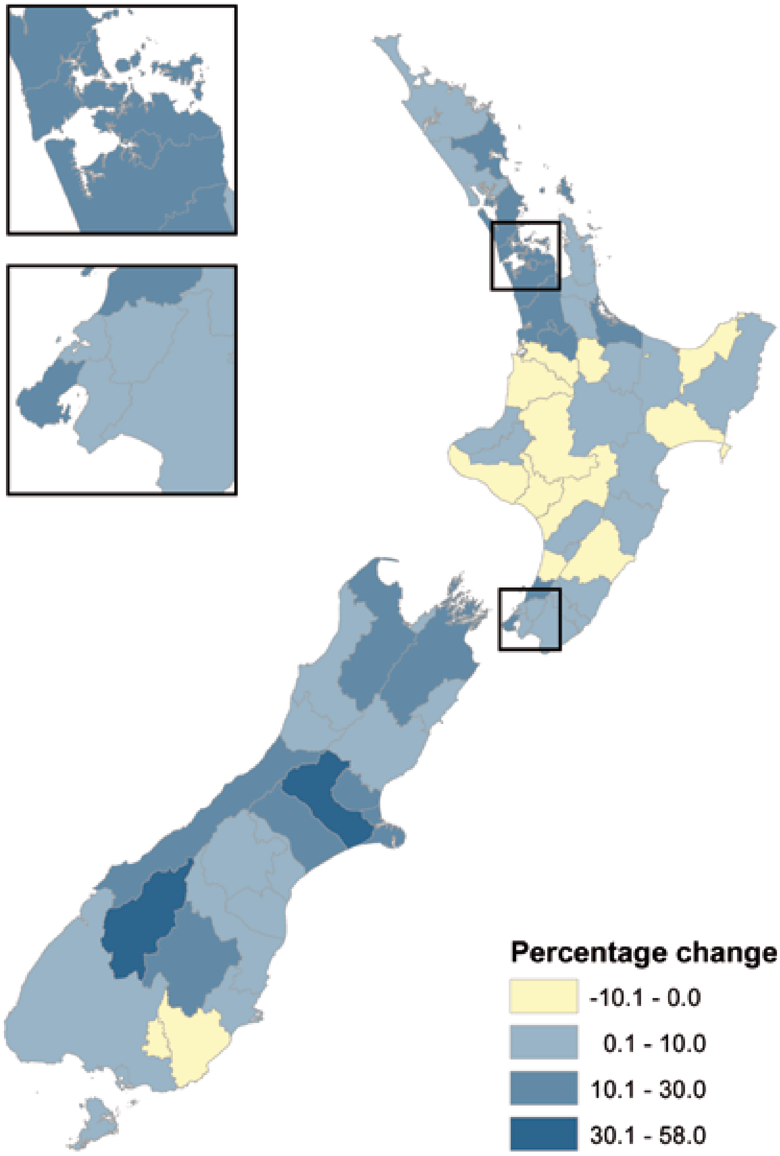


TABLE 3: PERCENTAGE CHANGE IN THE ESTIMATED POPULATION BY AREA, 2001 TO 2010

	New Zealand		North Island		South Island	
Population change		%		%		%
		12.6		13.1		11.0
Population increase	Territorial Authority	%	Territorial Authority	%	Territorial Authority	%
	Queenstown-Lakes	55.7	Rodney	27.4	Queenstown-Lakes	55.7
	Selwyn	39.9	Manukau	26.0	Selwyn	39.9
	Rodney	27.4	Franklin	22.3	Waimakariri	25.6
Population decrease						
	Ruapehu	-9.7	Ruapehu	-9.7	Gore	-3.5
	Wairoa	-8.9	Wairoa	-8.9	Clutha	-0.6
	South Waikato	-5.4	South Waikato	-5.4		

FIGURE 3: PERCENTAGE CHANGE IN POPULATION ESTIMATES BY TERRITORIAL AUTHORITY, 2001 TO 2010



Refer to Appendix 1 for a reference map of New Zealand featuring territorial authorities.

4.4.2 Greenhouse gas emissions

DPSEEA component: Pressure

Definition: Total greenhouse gas emissions for New Zealand

Relevance and interpretation:
Changes in the atmospheric abundance of greenhouse gases and aerosols, in solar radiation and in land surface properties alter the energy balance of the climate system. These changes are expressed in terms of radiative forcing which is used to compare how a range of human and natural factors drive warming or cooling influences on global climate. Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the increase in anthropogenic greenhouse gas concentrations (burning fossil fuels, deforestation, etc) and it is likely that anthropogenic warming has a discernible influence on many physical and biological systems (Hennessy 2007; IPCC 2007).

It has been estimated that New Zealand's total energy demand is likely to grow at an average rate of 2.4% per year from 2005 to 2025 (Electricity Commission 2005 cited in Hennessy 2007).

In 2010, New Zealand's total greenhouse gas emissions were 71,657 gigagrams carbon dioxide equivalent (Gg CO^2-e), an increase of 19.8% from 1990 levels of 59,797 Gg CO^2-e. The four emission sources that contributed the most to this increase in total emissions were road transport, dairy enteric fermentation, agricultural soils, and public electricity and heat production. In 2010, net removals were 18,307 Gg CO_2-e from land subject to afforestation, reforestation and deforestation (Ministry for the Environment 2012).

Since 1990 the relative proportions of greenhouse gases emitted by New Zealand have changed. In 1990, methane (CH_4) and carbon dioxide (CO_2) contributed equally to total emissions whereas in 2010 CO_2 was the predominant greenhouse gas in total emissions. The increase in CO_2 emissions corresponds to the growth in emissions from the energy sector (Ministry for the Environment 2012).

Computation: $(E_{t1} - E_{t0})/E_{t0} * 100$
Where E_{t1} = emissions at time 1
E_{t0} = emissions at time 0

Data source: New Zealand's Greenhouse Gas Inventory 1990–2010, Ministry for the Environment
http://www.mfe.govt.nz/publications/climate/greenhouse-gas-inventory-2012/index.html

Results:

Temporal trends, 2001 to 2010

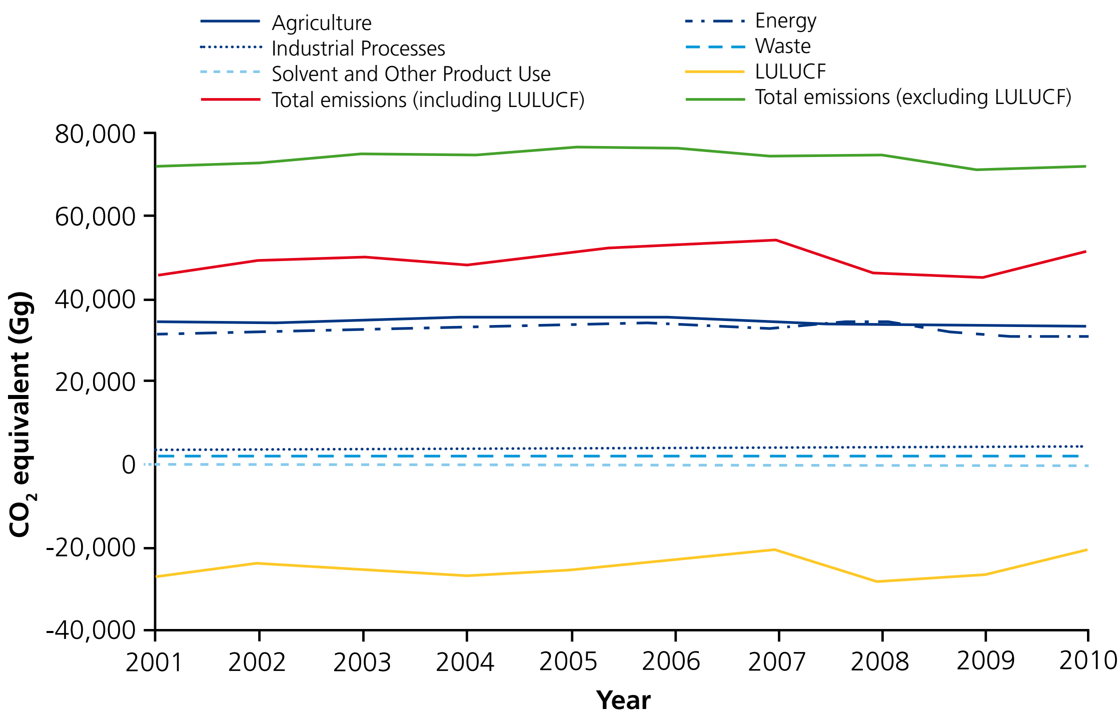
- Between 2001 and 2010, New Zealand's total emissions (excluding Land use, land-use change and forestry (LULUCF)) decreased by -0.7% while total emissions (including LULUCF) increased by 12.3% (Table 4).
- The agriculture and energy sectors are the major contributors to New Zealand's total emissions (Figure 4).
- The industrial processes sector was the only sector that had an increase in emissions (28.8%) while the solvent and other product use sector had the largest decrease (-34.6%). However, these sector's contributions to New Zealand's total emission are relatively small (Table 4; Figure 4).
- Carbon dioxide (CO_2) and methane (CH_4) are the predominant greenhouse gases making up New Zealand's total emissions. Between 2001 and 2010, CO_2 and CH_4 emissions decreased -0.6% and -4.5% respectively (Figure 5; Table 4).

TABLE 4: PERCENTAGE CHANGE IN NEW ZEALAND TOTAL GREENHOUSE GAS EMISSIONS BY SECTOR AND GREENHOUSE GAS, 2001 TO 2010

Total Greenhouse Gas Emissions	
Sector	%
Industrial processes	28.8
Energy	-1.7
Agriculture	-2.5
Waste	-7.0
Solvent and other product use	-34.6
Total (excluding LULUCF)	**-0.7**
LULUCF[1]	-23.5
Total (including LULUCF)	**12.3**
Greenhouse gas	%
HFCs	217.7
SF_6	84.4
N_2O	2.2
CO_2	-0.6
CH_4	-4.5
PCFs	-32.7
Total[2]	**-0.7**

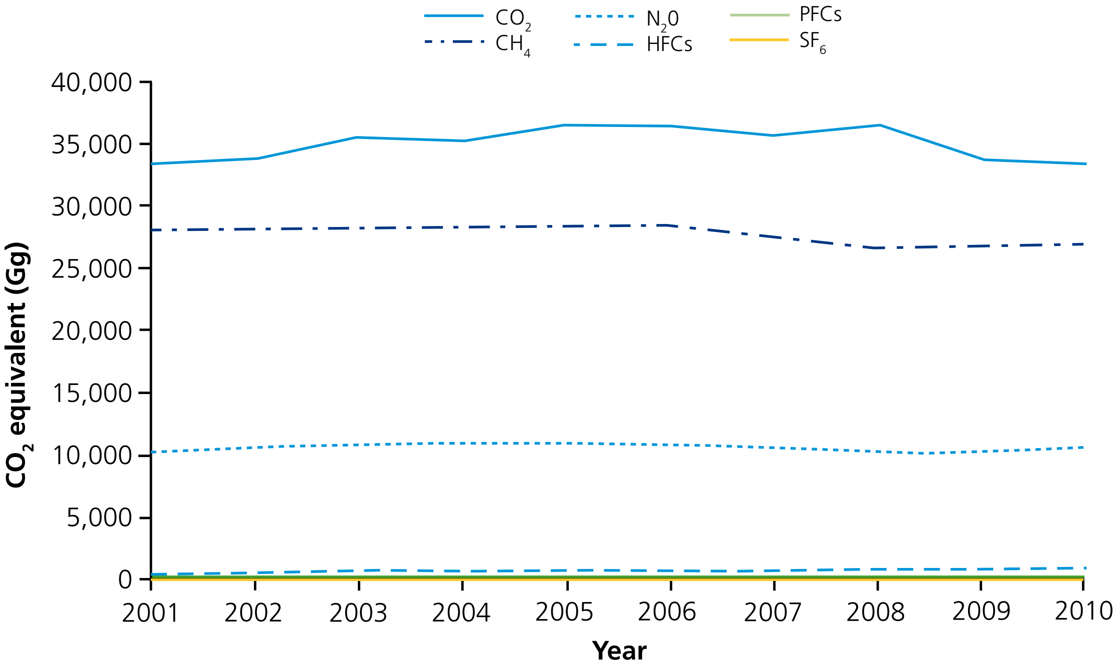
LULUCF = land use, land-use change and forestry; CH_4 = methane; CO_2 = carbon dioxide;
HFCs = hydroflurocarbons; N_2O = nitrous oxide; PCFs = perflurocarbons; SF_6 = sulphur hexafluoride
[1] includes net CO_2, CH_4 and N_2O from LULUCF
[2] total emissions exclude net removals from the LULUCF sector (CO_2 emissions excluding net CO_2, CH_4 emissions excluding CH_4, N_2O emissions excluding N_2O from LULUCF)

FIGURE 4: NEW ZEALAND'S TOTAL GREENHOUSE GAS EMISSIONS BY SECTOR, 2001 TO 2010



LULUCF = land use, land-use change and forestry
LULUCF and total emissions (including LULUCF) includes net CO_2, CH_4 and N_2O from LULUCF

FIGURE 5: NEW ZEALAND'S TOTAL GREENHOUSE GAS EMISSIONS (EXCLUDING LULUCF)[1] BY GREENHOUSE GAS, 2001 TO 2010



LULUCF = land use, land-use change and forestry

[1] Total emissions exclude emissions and removals from the LULUCF sector (CO_2 emissions excluding net CO_2, CH_4 emissions excluding CH_4 and N_2O emissions excluding N_2O from LULUCF)

4.4.3 Climate – ambient temperature

DPSEEA component: Pressure

Definition: Mean monthly ambient temperature by geographical area (territorial authority)

Relevance and interpretation:
Changes in the atmospheric abundance of greenhouse gases and aerosols, in solar radiation and in land surface properties alter the energy balance of the climate system. These changes are expressed in terms of radiative forcing which is used to compare how a range of human and natural factors drive warming or cooling influences on global climate. Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the increase in anthropogenic greenhouse gas concentrations (burning fossil fuels, deforestation, etc) and it is likely that anthropogenic warming has a discernable influence on many physical and biological systems (Hennessy 2007; IPCC 2007).

Globally temperature has increased with the linear warming trend over the last 50 years (0.13°C [0.10°C to 0.16°C] per decade) nearly twice that for the last 100 years. The total temperature increase from 1850–1899 to 2001–2005 is 0.76°C [0.57°C to 0.95°C]. For the next two decades, a warming of about 0.2°C per decade is projected for a range of SRES emission scenarios. Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected (IPCC 2007).

In New Zealand, temperatures increased by 1.1°C between the decades 1861–1870 and 1981–1990. Temperatures increase sharply after the 1940s, but recently annual mean warming has slowed (NIWA 2012a) with predictions of an average warming of 0.2 to 2.0°C by 2040 and 0.7 to 5.1°C by 2090. The annual-average pattern of warming is fairly uniform over the country, although slightly greater over the North Island than the South Island. In addition, daily temperature extremes are predicted to vary with a large decrease in the number of frost days for the central North Island and in the South Island as the 21st Century progresses. An increase in the number of days above 25°C is also expected, particularly in the north (NIWA 2012b).

Pressures such as production and consumption patterns, ecological change, climate change, land-use change and livestock numbers can exacerbate and/or alter transmission and transmission pathways for pathogens (eg, *Salmonella*). For example, implications of climate change such as increased temperatures or rainfall may facilitate the multiplication, survival and distribution of *Salmonella* and agricultural land-use and livestock numbers may affect water quality and therefore *Salmonella* transmission, which may pose a health risk. Impacts of these pressures can be measured using the state, exposure, and effect indicators.

Downstream effects of climate change include, ecosystem degradation, resource scarcity, and migration pressures further straining limited natural resources and increasing population density.

There may be geographical differences in the ambient temperature within the defined geographical areas that may be masked when data are aggregated to larger areas. There may also be marked variations between months that may be masked when data are aggregated to annual means. Therefore this indicator should be interpreted with caution.

Computation:
Mean monthly ambient temperature (°C)

Mean annual ambient temperature (°C)

Percentage change in ambient temperature:

$$(T_{t1} - T_{t0})/T_{t0} * 100$$

Where T_{t1} = temperature at time 1

T_{t0} = temperature at time 0

Data source: National Climate Database, NIWA http://www.niwa.co.nz/

Results:
Temporal trends, 2001 to 2010

- Between 2001 and 2010, the mean annual temperature for New Zealand increased by 1.7% (13.2 to 13.4°C). The South Island showed a greater increase than the North Island (2.5% and 1.5%, respectively). There were marked variations in the percentage change between months.
- Figure 6 shows the variation in mean monthly temperature between 2001 and 2010 for New Zealand and the North and South Islands.

Spatial trends, 2010

- In 2010, the mean annual temperature was (Table 5):
  - New Zealand: 13.4°C (range: 7.8–18.9°C)
  - North Island: 14.0°C (range: 8.4–19.4°C)
  - South Island: 10.7°C (range: 4.2–15.9°C)
- In all three locations the coldest month was July and the warmest was February.
- The highest mean monthly temperatures were recorded in February in the following territorial authorities (Table 6):
  - Auckland: 21.9°C
  - Rodney: 21.7°C
  - North Shore & Waitakere: 21.6°C
- The lowest mean monthly temperatures were recorded in the following territorial authorities (Table 6):
  - Mackenzie: -0.1°C (June) & 0.7°C (July)
  - Central Otago: 2.2°C (July)
- There were geographical differences in temperature within the defined geographic areas and marked variations between months (Table 6).

FIGURE 6: MEAN MONTHLY AMBIENT TEMPERATURE BY MONTH, YEAR AND AREA, 2001 TO 2010

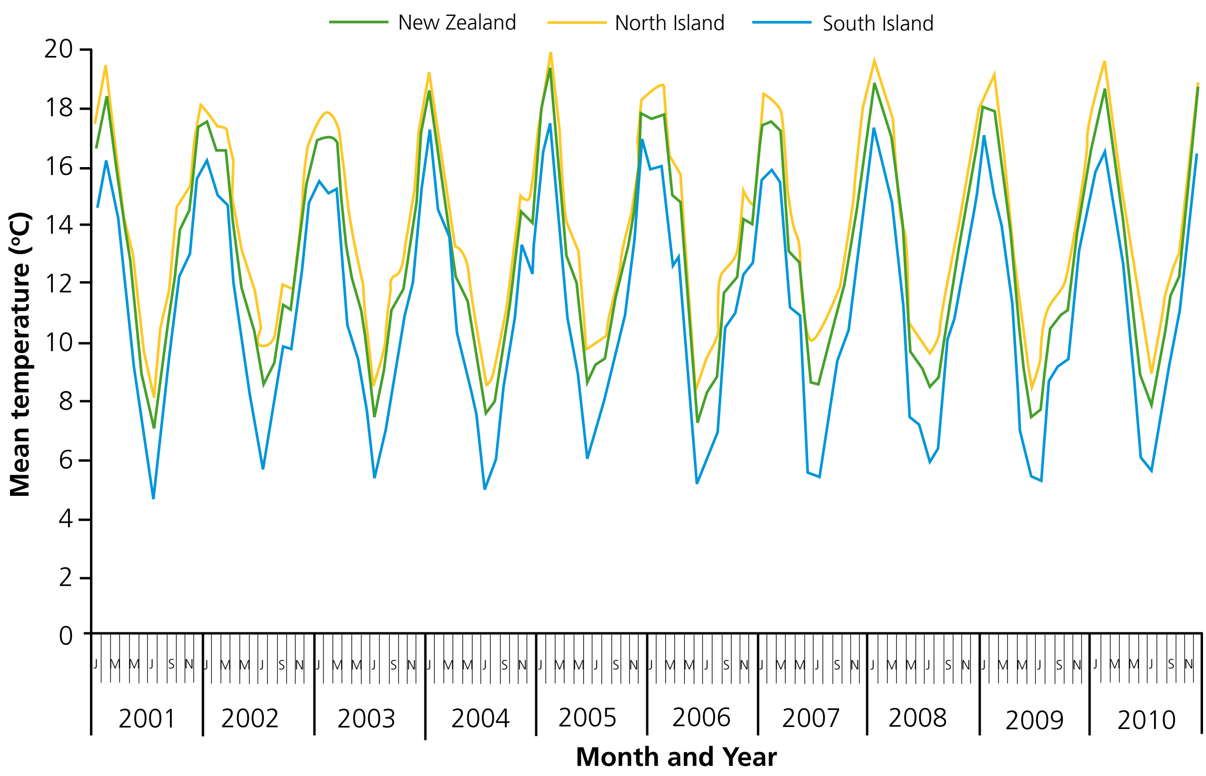


TABLE 5: MEAN ANNUAL TEMPERATURE BY AREA, 2010

	New Zealand		North Island		South Island	
Mean temperature		°C		°C		°C
		13.4		14.0		10.7
Warmest	Territorial Authority	°C	Territorial Authority	°C	Territorial Authority	°C
	Auckland	16.8	Auckland	16.8	Nelson	13.8
	Rodney	16.5	Rodney	16.5	Tasman	13.7
	Kaipara	16.4	Kaipara	16.4	Marlborough	13.2
	Whanagrei	16.4	Whanagrei	16.4	Buller	13.2
Coldest						
	Mackenzie	9.1	Rangitikei	12.0	Mackenzie	9.1
	Gore	10.0	Taupo	12.3	Gore	10.0
	Southland	10.0	Upper Hutt	13.0	Southland	10.0
			Lower Hutt	13.0		
			Tararua	13.0		

TABLE 6: MEAN MONTHLY AMBIENT TEMPERATURE IN NEW ZEALAND BY MONTH AND TERRITORIAL AUTHORITY, 2010

Legend: < -0.1°C | 0.0-5.9°C | 6.0-10.9°C | 11.0-15.9°C | 16.0-20.9°C | 21.0°C > | no data

Territorial authority	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Month											
Far North District	19.2	20.5	18.5	17.1	14.6	12.6	12.3	13.1	13.7	13.6		
Whangarei District	20.2	21.1	19.5	17.2	14.9	12.7	11.5	13.1	14.4	14.1	17.0	20.7
Kaipara District	20.2	21.1	19.5	17.2	14.9	12.7	11.5	13.1	14.4	14.1	17.0	20.7
Rodney District	19.8	21.7	19.6	18.1	15.5	13.4	12.0	12.9	13.8	14.4	16.9	19.6
North Shore City	20.0	21.6	19.1	16.9	14.8	12.9	11.2	12.9	14.0	14.5	17.0	20.5
Waitakere City	20.0	21.6	19.1	16.9	14.8	12.9	11.2	12.9	14.0	14.5	17.0	20.5
Auckland City	20.3	21.9	19.3	17.3	14.9	13.0	11.5		14.1	14.7	17.1	20.4
Manukau City	19.9	21.6	19.1	16.9	14.3	12.1	10.6	12.4	13.6	14.2	16.8	20.3
Papakura District	18.2	20.0	16.9	15.4	13.4	10.6	9.7	11.0	12.7		15.6	19.1
Franklin District	17.7	19.5	17.1	15.4	12.7	10.6	9.0	10.7	11.9	12.7	15.5	18.6
Thames-Coromandel District	19.5	21.0	18.4	16.2	13.8	11.5	9.6	12.0	13.1		16.5	19.8
Hauraki District	19.3	21.0	18.1	15.8	13.1	11.4	8.8		13.0	13.6	17.2	19.9
Waikato District	18.3	20.3	16.8	14.9	11.9	9.6	8.3	10.2	12.0	12.8	15.7	19.3
Matamata-Piako District	18.0	20.0	16.6	14.7	11.8	9.0	7.9	9.9	11.3	12.3	15.5	18.5
Hamilton City	18.3	20.3	16.8	14.9	11.9	9.6	8.3	10.2	12.0	12.8	15.7	19.3
Waipa District	18.3	20.3	16.8	14.9	11.9	9.6	8.3	10.2	12.0	12.8	15.7	19.3
South Waikato District	17.2	19.2	16.0	13.7	11.0	8.7	7.3	9.2	10.6	11.4	14.7	17.7
Otorohanga District	18.3	20.3	16.8	14.9	11.9	9.6	8.3	10.2	12.0	12.8	15.7	19.3
Waitomo District	18.3	20.3	16.8	14.9	11.9	9.6	8.3	10.2	12.0	12.8	15.7	19.3
Taupo District	16.6	18.7	15.1	12.8	9.8	7.8	5.9	8.3	9.8	10.9	14.3	18.1
Western Bay of Plenty District	18.4	20.2	17.5	15.2	12.9	10.3	9.4	11.2	12.6	13.3	15.6	18.8
Tauranga City	19.5	21.2	19.0	16.2	13.9	11.6	10.1	11.8	13.4	14.7	17.1	19.8
Rotorua District	17.2	19.2	16.0	13.7	11.0	8.7	7.3	9.2	10.6	11.4	14.7	17.7
Whakatane District	18.8	20.3	18.0	15.2	13.0	10.2	9.1	11.4	12.6	13.1	16.1	19.1
Kawerau District	17.2	19.2	16.0	13.7	11.0	8.7	7.3	9.2	10.6	11.4	14.7	17.7
Opotiki District		20.2	17.7	15.3	13.2	10.3	9.8	11.3	11.9	12.8	15.5	18.3
Gisborne District	18.9	20.0	18.0	15.5	12.7	10.3	9.8	11.6	13.8	12.9	15.1	18.9
Wairoa District	18.5	19.7	17.2	14.6	12.1	9.5	9.0	10.8	13.1	12.7	15.3	18.9
Hastings District	18.4	19.0	17.8	14.7		10.0	8.7	10.8	12.9	12.6	15.0	18.8
Napier City	18.4	19.0	17.8	14.7		10.0	8.7	10.8	12.9	12.6	15.0	18.8
Central Hawke's Bay District	18.4	19.0	17.8	14.7		10.0	8.7	10.8	12.9	12.6	15.0	18.8
New Plymouth District	17.4	19.4	16.8	15.3	13.2	11.0	9.4	10.7	12.4	12.7	14.8	17.8
Stratford District	17.4	19.4	16.8	15.3	13.2	11.0	9.4	10.7	12.4	12.7	14.8	17.8
South Taranaki District	17.4	19.4	16.8	15.3	13.2	11.0	9.4	10.7	12.4	12.7	14.8	17.8
Ruapehu District	17.6	19.6	15.5	13.6	10.6	8.5	6.8	9.4	10.8	12.5	15.6	18.1
Wanganui District	17.0	18.7	16.5	15.0	12.5	10.7	8.8	10.9	12.4	12.5	14.7	18.4
Rangitikei District	16.5	18.4	14.2	11.7	9.4	7.4	5.6	8.3	9.4	10.8	14.1	18.0
Manawatu District	17.5	18.9	16.2	13.9	11.6	9.5	8.0	10.4	11.7	12.4	14.8	18.2
Palmerston North City	17.5	18.9	16.2	13.9	11.6	9.5	8.0	10.4	11.7	12.4	14.8	18.2
Tararua District	17.0	18.3	15.8	13.4	11.0	8.7	7.1	9.7	11.2	11.7	14.6	17.8
Horowhenua District	17.2	18.4	15.8	14.0	12.0	9.6	7.9	10.3	11.6	11.9	14.3	17.7
Kapiti Coast District	16.3	17.9	15.9	14.4	11.9	9.9	7.4	10.5	11.9	11.9	14.0	17.3
Porirua City	16.6	18.3	17.0	15.7	13.2	10.8	9.2	11.3	12.7	12.7	15.0	17.9
Upper Hutt City	17.4	18.3	15.9	14.4	11.4	8.5	7.1	9.5	11.3	11.1	14.0	17.2
Hutt City	17.4	18.3	15.9	14.4	11.4	8.5	7.1	9.5	11.3	11.1	14.0	17.2
Wellington City	16.8	17.9	16.9	15.7	12.7	10.3	8.4	10.8	12.4	12.1	15.0	17.3
Masterton District		18.1	16.1	13.6	11.2							
Carterton District		18.1	16.1	13.6	11.2							
South Wairarapa District	17.8	18.3	16.2	14.3	11.4	8.7	7.1	9.9	11.9	11.3	15.1	18.2
Tasman District	18.0	18.3	16.2	13.5	12.1	9.3	8.1	10.9	11.5	12.3	15.7	18.1
Nelson City	18.4	19.4	17.2	14.5	12.0	9.0	7.9	9.8	10.9	12.4	16.0	18.2
Marlborough District	18.3	17.9	16.4	14.2	10.8	8.2	6.9	9.4	11.1	11.4	15.3	18.0
Kaikoura District	15.9	16.8	15.9	14.6	11.1	8.5	7.6	8.9	11.5	11.2	14.2	17.7
Buller District	16.5	17.8	15.3	14.0	11.8	9.9	9.3	10.3	10.5	11.5	14.4	16.6
Grey District	16.2	17.2	14.3	13.8	11.3	9.0	8.3	10.2	10.1	11.6	14.2	16.4
Westland District	15.8	16.5	14.1	13.4	10.6	8.4	7.6	9.5	9.2	10.8	13.6	15.6
Hurunui District	16.8	16.8	15.0	13.4	9.8	6.8	6.0	8.4	10.8	10.9	14.6	17.4
Waimakariri District	16.8	16.8	15.0	13.4	9.8	6.8	6.0	8.4	10.8	10.9	14.6	17.4
Christchurch City	16.6	16.9	15.4	13.2	9.4	6.2	5.4	8.0	10.2	10.9	14.7	17.8
Selwyn District	16.2	17.5	16.1	14.3	9.6	6.1	5.8	8.0	10.6	11.3	15.1	17.7
Ashburton District	16.1	17.1	15.4	13.8	9.2		5.1	7.8	10.4	11.9	15.8	17.4
Timaru District	15.7	15.9	14.4	12.3	8.6	5.0	4.6	7.3	9.1	10.3	13.9	16.1
Mackenzie District	14.5	16.1	13.7	11.2	5.8	-0.1	0.7	3.4	6.3	9.2	13.7	14.6
Waimate District	14.6	15.1	14.4	12.1	8.3	5.8	5.2	7.0	8.9	10.2	13.2	15.3
Waitaki District	14.6	15.1	14.4	12.1	8.3	5.8	5.2	7.0	8.9	10.2	13.2	15.3
Central Otago District	17.7	18.7	15.7	12.5	7.5	2.7	2.2	6.2	8.9	12.3	16.3	17.8
Queenstown-Lakes District	15.7	16.8	14.2	11.3	6.5	3.1	2.8	5.3	7.3	10.3	13.8	15.4
Dunedin City	14.3	15.1	14.2	11.8	7.6	4.9	4.1	6.4	8.4	10.7	13.8	15.3
Clutha District	14.4	15.3	13.5	11.6	8.2	4.9	5.3	7.1	7.8	11.2	14.0	15.7
Southland District	14.3	15.1	13.3	11.0	7.3	3.5	3.8	5.9	7.4	10.5	13.8	14.5
Invercargill City	14.1	14.3	12.9	11.6	7.9	5.1	5.5	6.9	8.1	10.5	13.8	14.4
Gore District	13.4	14.3	12.7	10.8	7.3	4.3	4.5	6.5	7.7	10.3	13.6	14.1

4.4.4 Climate – rainfall

DPSEEA component: Pressure

Definition: Total and mean monthly rainfall by geographical area (territorial authority)

Relevance and interpretation:
Changes in the atmospheric abundance of greenhouse gases and aerosols, in solar radiation and in land surface properties alter the energy balance of the climate system. These changes are expressed in terms of radiative forcing which is used to compare how a range of human and natural factors drive warming or cooling influences on global climate. Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the increase in anthropogenic greenhouse gas concentrations (burning fossil fuels, deforestation, etc) and it is likely that anthropogenic warming has a discernible influence on many physical and biological systems (Hennessy 2007; IPCC 2007).

In New Zealand, rainfall has increased in the south-west and decreased in the north-east of the country (Salinger and Mullan 1999). The projected annual-average rainfall change pattern is for an increase in the west (up to 5% by 2040 and 10% by 2090) and a decrease in the east and north (exceeding 5% in places by 2090) of New Zealand. This annual pattern of wetter in the west and drier in the east is dominated by the winter and spring seasons (NIWA 2012b). Heavy rainfall is likely to get heavier and/or more frequent (NIWA 2008). Rain events are likely to become more intense, leading to greater storm runoff, but with lower river levels between events (Hennessy 2007).

Pressures such as production and consumption patterns, ecological change, climate change, land-use change and livestock numbers can exacerbate and/or alter transmission and transmission pathways for pathogens (eg, *Salmonella*). For example, implications of climate change such as increased temperatures or rainfall may facilitate the multiplication, survival and distribution of *Salmonella* and agricultural land-use and livestock numbers may affect water quality and therefore *Salmonella* transmission, which may pose a health risk. Impacts of these pressures can be measured using the state, exposure, and effect indicators.

Downstream effects of climate change include, ecosystem degradation, resource scarcity, and migration pressures further straining limited natural resources and increasing population density.

There may be geographical differences in the total rainfall within the defined geographical areas that may be masked when data are aggregated to larger areas. There may also be marked variations between months that may be masked when data are aggregated to annual totals and means. Therefore this indicator should be interpreted with caution.

Computation:
Total monthly rainfall (mm)

Mean monthly rainfall (mm)

Mean annual rainfall (mm)

Percentage change in mean annual rainfall:

$$(R_{t1} - R_{t0})/R_{t0} * 100$$

Where R_{t1} = rainfall at time 1

R_{t0} = rainfall at time 0

Data source: National Climate Database, NIWA http://www.niwa.co.nz/

Results:

Temporal trends, 2001 to 2010

- Between 2001 and 2010, the mean annual rainfall for New Zealand decreased by -1.0% (93 to 92 mm). The North Island also had a decrease, -6.3% (104 to 97 mm), while the South Island had an increase of 17.3% (69 to 82 mm). There were marked variations in the percentage change between months.
- Figure 7 shows the variation in mean monthly rainfall between 2001 and 2010 for New Zealand and the North and South Islands.

Spatial trends, 2010

- In 2010, the mean monthly rainfall was (Table 7):
  - New Zealand: 92 mm (range: 33–163 mm), March was driest and May wettest
  - North Island: 97 mm (range: 28–188 mm), March was driest and August wettest
  - South Island: 82 mm (range: 44–146 mm), February was driest and May wettest
- The highest total monthly rainfalls were recorded in the following territorial authorities (Table 8):
  - Westland: 441 mm (September) & 413 mm (December)
  - Western Bay of Plenty: 413 mm (August)
- The lowest total monthly rainfalls were recorded in the following territorial authorities (Table 8):
  - North Shore, Waitakere, Auckland, Manukau, and Mackenzie: 5 mm (February)
  - Marlborough: 5 mm (April)
  - Rodney: 7 mm (March)
- There were geographical differences in rainfall within the defined geographic areas and marked variations between months (Table 8).

FIGURE 7: MEAN OF MONTHLY TOTAL RAINFALL BY MONTH, YEAR AND AREA, 2001 TO 2010

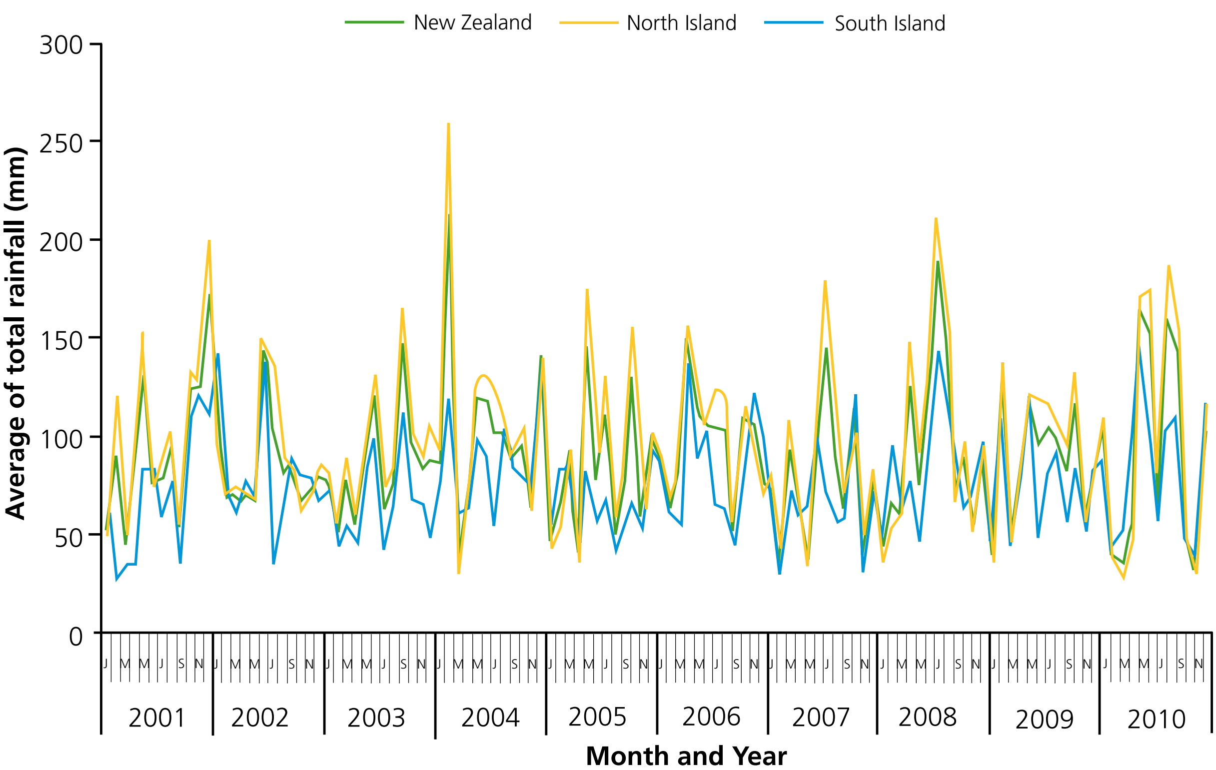


TABLE 7: MEAN MONTHLY AND MEAN ANNUAL RAINFALL BY AREA, 2010

	New Zealand		North Island		South Island	
Mean monthly rainfall		mm		mm		mm
	92 (range: 33–163)		97 (range: 28–188)		82 (range: 44–146)	
Mean annual rainfall						
Driest	Territorial Authority	mm	Territorial Authority	mm	Territorial Authority	mm
	Central Otago	29	Masterton	53	Central Otago	29
	Waimate	46	Carterton	53	Waimate	46
	Waitaki	46	Rangitikei	54	Waitaki	46
Wettest						
	Westland	239	Western Bay of Plenty	150	Westland	239
	Grey	192	Opotiki	146	Grey	192
	Buller	151	Whakatane	131	Buller	151

TABLE 8: TOTAL RAINFALL IN NEW ZEALAND BY MONTH AND TERRITORIAL AUTHORITY, 2010

Legend: 0.0-100.9mm | 101.0-200.9mm | 201.0-300.9mm | 301.0-400.9mm | 401.0-500.9mm | no data

	Month											
Territorial authority	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Far North District		56.4	35.8	85.0	257.4	141.8	185.3	248.9	118.2	40.6	36.3	122.6
Whangarei District	39.8	65.0	7.6	40.8	232.2	67.1	159.0	166.8	78.4	35.4	14.2	98.2
Kaipara District	39.8	65.0	7.6	40.8	232.2	67.1	159.0	166.8	78.4	35.4	14.2	98.2
Rodney District	45.0	17.6	6.6	14.8	233.4	112.6	113.4		104.8	43.4	20.2	128.0
North Shore City	44.0	4.6	7.6	56.0	162.8	160.8	87.0	187.4	112.0	19.8	22.3	94.4
Waitakere City	44.0	4.6	7.6	56.0	162.8	160.8	87.0	187.4	112.0	19.8	22.3	94.4
Auckland City	44.0	4.6	7.6	56.0	162.8	160.8	87.0	187.4	112.0	19.8	22.3	94.4
Manukau City	44.0	4.6	7.6	56.0	162.8	160.8	87.0	187.4	112.0	19.8	22.3	94.4
Papakura District	37.6	31.7	10.5	47.1	137.9	191.2	86.8	254.2	135.3	27.9	46.1	105.2
Franklin District	92.2	11.6	13.6	51.0	128.0	230.0	103.2	213.6	149.6	41.2	38.4	91.0
Thames-Coromandel District	63.5	17.9	26.5	32.8	202.2	192.6	107.7	240.3	135.2		27.6	91.3
Hauraki District	82.4	35.8	12.6	75.2	147.8	179.8	120.4		122.2	32.2	57.0	66.9
Waikato District	191.6	24.4	20.2	36.6	120.4	222.6	65.8	196.1	180.8	41.2	16.0	120.2
Matamata-Piako District	138.0	36.2	19.2	32.6	152.2	145.2			196.5	39.0	33.0	98.2
Hamilton City	191.6	24.4	20.2	36.6	120.4	222.6	65.8	196.1	180.8	41.2	16.0	120.2
Waipa District	191.6	24.4	20.2	36.6	120.4	222.6	65.8	196.1	180.8	41.2	16.0	120.2
South Waikato District	191.6	24.4	20.2	36.6	120.4	222.6	65.8	196.1	180.8	41.2	16.0	120.2
Otorohanga District	172.2	38.2	23.0	41.4	285.2	211.5	37.2	289.5	152.0	49.0	54.2	82.2
Waitomo District	191.6	24.4	20.2	36.6	120.4	222.6	65.8	196.1	180.8	41.2	16.0	120.2
Taupo District	107.4	27.8	18.6	33.4	90.2	184.2	19.6	173.0	142.3	28.4	15.8	58.4
Western Bay of Plenty District	74.8	36.2	19.2	83.6	311.0	283.0	68.2	413.4	224.8	35.6	61.4	188.8
Tauranga City	178.2	10.0	16.8	26.6	254.2	201.5	51.8	274.4	139.5	23.4	35.8	113.2
Rotorua District	172.2	38.2	23.0	41.4	285.2	211.5	37.2	289.5	152.0	49.0	54.2	82.2
Whakatane District	132.4	29.4	29.1	79.8	294.2	320.9	60.8	251.9	149.3	55.1	39.4	130.8
Kawerau District	172.2	38.2	23.0	41.4	285.2	211.5	37.2	289.5	152.0	49.0	54.2	82.2
Opotiki District	205.0	20.0	55.8	67.4	324.5	286.1	59.9	332.8	147.7	55.9	42.4	153.8
Gisborne District	171.0	22.8	21.4	75.4	180.2	122.7	184.6	100.3	41.0	199.4	37.4	24.2
Wairoa District	280.6	33.4	26.4	108.2	177.8	149.6	201.6	148.8	26.4	234.0	27.9	19.2
Hastings District	195.0	32.0	16.6	40.8	194.6	130.7	83.8	95.4	49.2	139.0	28.8	32.8
Napier City	195.0	32.0	16.6	40.8	194.6	130.7	83.8	95.4	49.2	139.0	28.8	32.8
Central Hawke's Bay District	195.0	32.0	16.6	40.8	194.6	130.7	83.8	95.4	49.2	139.0	28.8	32.8
New Plymouth District	60.0	149.6	65.8	54.4	223.0	264.0	59.0	204.2	235.6	36.0	26.8	180.8
Stratford District	60.0	149.6	65.8	54.4	223.0	264.0	59.0	204.2	235.6	36.0	26.8	180.8
South Taranaki District	60.0	149.6	65.8	54.4	223.0	264.0	59.0	204.2	235.6	36.0	26.8	180.8
Ruapehu District	145.0	53.8	44.2	34.9	111.2	174.1	41.6	227.4	324.0	34.7	30.6	185.0
Wanganui District	58.6	51.4	54.8	31.4	116.0	110.1	22.4	155.4	198.0	34.3	10.0	60.8
Rangitikei District	53.5	21.7	24.6	26.4	89.5	81.9	35.1	79.0	130.7	25.1	25.7	59.1
Manawatu District	70.8	47.6	38.0	43.6	54.4	113.2	43.2	118.0	240.9	42.2	48.3	67.6
Palmerston North City	70.8	47.6	38.0	43.6	54.4	113.2	43.2	118.0	240.9	42.2	48.3	67.6
Tararua District	161.4	33.1	30.5	24.2	143.8	114.8	65.6	121.6	244.9	67.2	20.7	60.7
Horowhenua District	88.0	58.8	42.8	54.4	51.6	126.8	38.4	125.4	188.6	28.2	35.0	92.0
Kapiti Coast District	44.0	30.6	31.7	59.0	69.6	145.8	39.2	113.4	230.2	55.0	18.6	99.8
Porirua City	35.1	19.8	22.7	39.6	192.7	159.9	48.6	131.0	179.1	66.9	26.1	95.6
Upper Hutt City	65.0	31.2	48.4	50.8	110.0	178.2	92.6	149.2	236.0	80.0	28.8	129.9
Hutt City	65.0	31.2	48.4	50.8	110.0	178.2	92.6	149.2	236.0	80.0	28.8	129.9
Wellington City	72.8	16.8	34.2	27.2	171.4	140.3	92.4	165.8	151.6	71.8	21.4	91.0
Masterton District		23.4	44.2	13.4	138.8				102.6	43.8	31.4	27.0
Carterton District		23.4	44.2	13.4	138.8				102.6	43.8	31.4	27.0
South Wairarapa District	73.8	10.8	37.0	11.2	117.4	95.2	82.6	136.6	81.4	35.4	30.6	26.2
Tasman District	90.0	21.6	25.6	60.6	219.0	217.2	50.6	169.8	162.0	14.2	18.0	242.0
Nelson City	97.2	28.6	31.0	28.6	137.8	153.2	29.0	126.8	123.2	5.6	22.6	183.4
Marlborough District	61.2	10.6	44.2	5.4	190.6	195.9	66.6	114.8	141.2	26.2	33.4	126.3
Kaikoura District	20.2	21.6	68.4	10.2	184.6	132.4	98.0	75.4	39.2	34.8	35.2	16.8
Buller District	165.0	113.8	100.9	134.2	109.5	201.0	111.6	159.5	316.4	111.6	41.8	242.4
Grey District	217.4	147.9	177.3	230.7	116.3	179.9	153.3	208.2	369.3	120.4	51.9	333.7
Westland District	260.4	194.2	183.4	246.6	176.3	211.4	172.6	337.7	440.5	143.8	87.8	413.0
Hurunui District	25.4	31.2	18.6	12.8	147.0	78.4	68.8	79.6	31.6	22.4	40.4	32.8
Waimakariri District	25.4	31.2	18.6	12.8	147.0	78.4	68.8	79.6	31.6	22.4	40.4	32.8
Christchurch City	32.6	18.2	22.4	24.0	163.8	93.1	67.6	86.4	42.0	22.0	53.0	35.2
Selwyn District	94.5	34.1	29.3	24.2	208.2	95.1	63.4	97.6	74.6	43.8	57.0	54.3
Ashburton District	69.0	19.3	25.0	37.4	205.8	79.0	44.5	105.9	20.5	31.2	47.6	59.7
Timaru District	36.6	23.2	30.8	36.8	171.0	65.6	44.4	95.8	11.6	19.8	32.2	48.8
Mackenzie District	94.5	5.4	15.7	42.3	138.2	60.5	4.5	82.9	48.0	15.5	15.8	126.4
Waimate District	17.8	18.8	14.1	37.6	203.0	46.2	32.0	72.4	9.6	21.6	27.6	51.4
Waitaki District	17.8	18.8	14.1	37.6	203.0	46.2	32.0	72.4	9.6	21.6	27.6	51.4
Central Otago District	60.7	18.1	12.1	32.7	30.8	33.7	10.3	28.6	29.0	19.0	10.4	59.1
Queenstown-Lakes District	82.8	19.0	52.2	140.0	79.4	66.4	40.6	81.8	84.2	56.4	12.6	128.2
Dunedin City	52.8	40.0	28.6	62.8	243.2	62.2	17.2	61.0	57.6	33.8	49.2	107.8
Clutha District	99.1	33.1	30.0	86.8	96.9	49.7	21.9	37.8	89.1	68.9	34.9	42.6
Southland District	139.6	47.4	62.6	141.4	59.2	68.0	19.8	76.4	78.4	72.6	44.2	110.0
Invercargill City	118.4	57.4	118.0	151.2	66.0	81.8	51.2	70.2	192.2	81.6	58.8	85.2
Gore District	121.4	51.6	61.6	149.6	52.2	77.6	23.8	53.1	98.2	76.6	52.2	96.6

4.4.5 Drinking water quality – bacteriological compliance

DPSEEA component: State

Definition: Proportion of registered drinking water supplies in each grade by geographic area (territorial authority)

Relevance and interpretation:

When the state of the environment is altered ecological and other changes may result. These changes in turn influence factors such as pathogen behaviour, disease transmission pathways, exposures and downstream health effects.

Water-borne illnesses can occur when humans ingest or come into contact with water that contains pathogenic organisms. Pathogens can enter water supplies from human and animal wastes. Both surface- and ground- waters (rain, rivers, lakes, aquifers etc) can become contaminated via inadequately treated wastewater, animal manure, runoff from land and urban environments. Treatment plants can be used to remove, or inactivate, pathogens in the water. However, should the source of an untreated or inadequately treated drinking water supply become contaminated, the water is likely to be unsafe. In New Zealand, in order to reduce pathogens in wastewater, it is treated before it is discharged in to the environment. However, the extent and effectiveness of the treatment varies. Pathogens can also enter the water from animal manure. This can occur in several ways including runoff as a result of rain washing manure from pasture in to waterways, animals directly defaecating in water and irrigation of dairy shed effluent back onto land (PCE 2012). Contamination of water from animal manure is of particular concern in New Zealand given the predominance of agricultural land use.

Untreated or inadequately treated drinking water contaminated with pathogens presents a significant risk to human health. The presence of *Escherichia coli* in drinking water indicates recent faecal contamination of the water. If *E. coli* is present, there is also a greater risk of pathogens being present. In New Zealand bacteriological compliance of drinking water is determined primarily using *E. coli* monitoring (Ministry of Health 2011). Thus, the presence of *E. coli* can be used as an indicator of the state of drinking water quality.

The overall burden of endemic drinking water-borne gastrointestinal disease in New Zealand has been estimated at 18,000 to 34,000 cases per year (Ball 2007).

There is increasing evidence that climate change-related alterations in temperature, rainfall (including extreme weather events), surface water availability and water quality could affect the burden of water-related diseases (Bates *et al.* 2008; Confalonieri *et al.* 2007; Hambling & Bandaranayake 2012). Bates *et al.* (2008) identify that higher water temperatures and changes in rainfall will affect water quality and exacerbate many forms of water pollution, with negative impacts on ecosystems, human health and water system reliability. Extreme droughts will reduce water flows and levels, increasing concentrations of pathogens from contaminated effluent discharges. Conversely, heavy rainfall can cause microbial contamination of surface water bodies and shallow groundwaters due to polluted surface runoff and discharges of untreated sewage from over-flowing combined sewage systems. This may increase the total microbial load in watercourses and raw water reservoirs (Kistemann *et al.* 2002).

Recent systematic reviews (Cann *et al.* 2012; ECDC 2012; Rizak & Hrudey 2008) have examined the relationships among climate variables, common risk factors, waterborne pathogens and outbreaks of waterborne diseases. The review by the ECDC (2012) reported associations between certain gastrointestinal diseases and air temperature, water temperature and precipitation events. Cann *et al.* (2012) found evidence to suggest that outbreaks of water-borne infectious disease follow extreme water-related climatic events. Contamination of the drinking water supply accounted for 53.7% of outbreaks following extreme water-related weather events. Rizak and Hrudey (2008) also found that heavy rainfall or runoff, as well as treatment process and system changes, are common risk factors for drinking water disease outbreaks.

Below are four main factors to consider when evaluating the relationship between health outcomes and exposure to changes in rainfall, water availability and quality (Confalonieri *et al.* 2007):

- linkages between water availability, household access to improved water, and the health burden due to diarrhoeal diseases;
- the role of extreme rainfall (intense rainfall or drought) in facilitating water-borne outbreaks of diseases through piped water supplies or surface water;

- effects of temperature and runoff on microbiological and chemical contamination of coastal, recreational and surface waters;
- direct effects of temperature on the incidence of diarrhoeal disease.

This indicator is a measure of the state of the microbiological quality of drinking water from registered drinking water supplies.

Computation: G_n/G_t*100
Where G_n = number of zones in a grade
G_t = total number of zones in all grades

Data source: Water Information New Zealand (WINZ) database, Ministry of Health

Results:

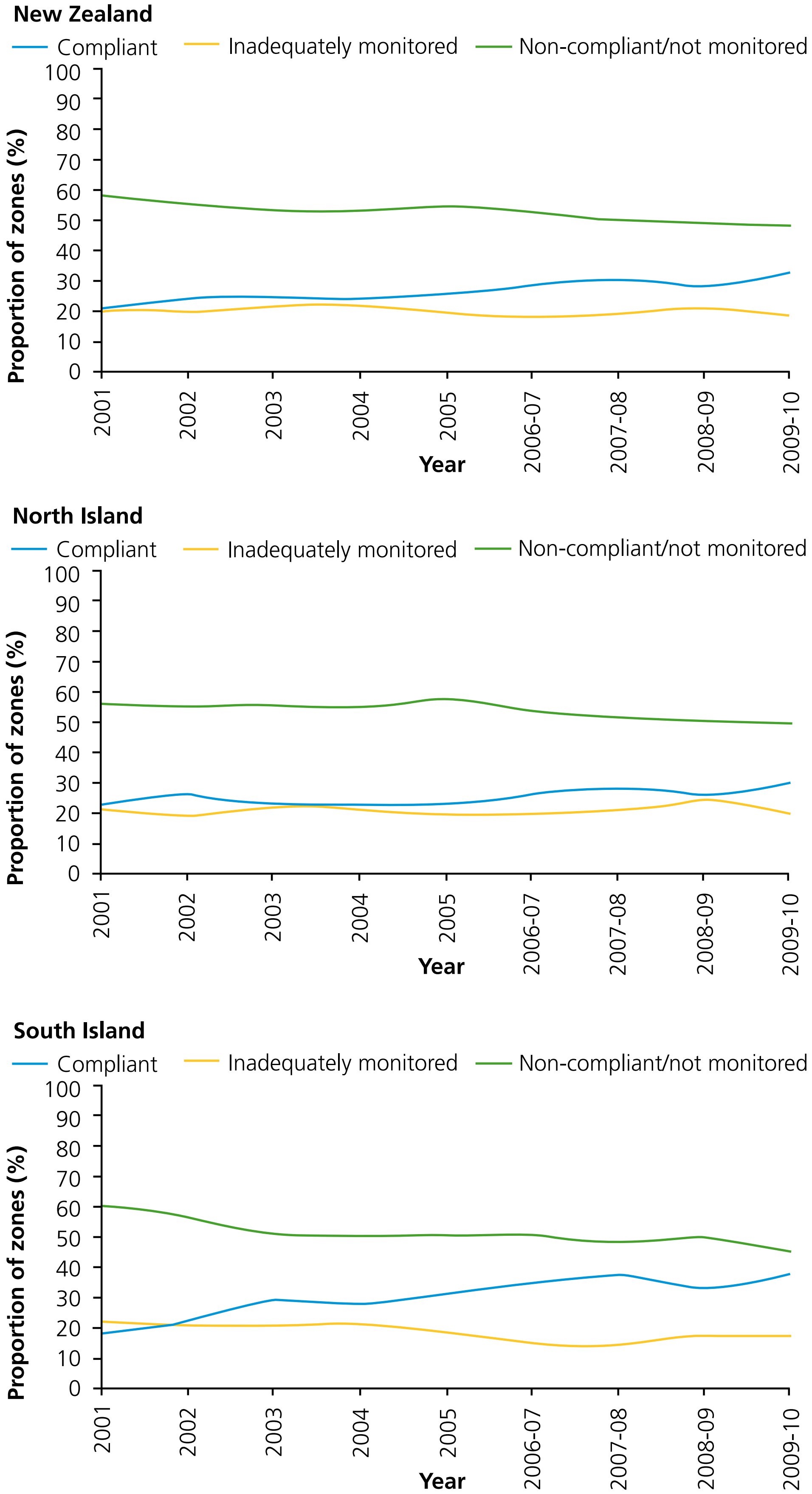
Temporal trends, 2001 to 2009-10

- Between 2001 and 2009-10, there was an increase in the proportion of drinking water zones graded 'compliant' (Figure 8; Table 9):
  - New Zealand: 56.3%
  - North Island: 36.9%
  - South Island: 100.8%
- While the proportion graded 'inadequately monitored' and 'non-compliant/not monitored' decreased (Figure 8; Table 9):
  - New Zealand: 'inadequately monitored' (-10.2%), 'non-compliant/not monitored' (-16.5%)
  - North Island: 'inadequately monitored' (-5.6%), 'non-compliant/not monitored' (-12.4%)
  - South Island: 'inadequately monitored' (-19.0%), 'non-compliant/not monitored' (-24.3%)
- There were marked geographical differences within the defined geographic areas.
- Figure 8 shows the variation in proportion of drinking water zones in each grade for New Zealand and the North and South Islands, 2001 to 2009-10.

Spatial trends, 2009-10

- In 2009-10, 32.6% of New Zealand's drinking water zones were graded 'compliant', 18.8% 'inadequately monitored', and 48.6% 'non-compliant/not monitored' (Figure 8).
- The South Island had a higher proportion of drinking water zones graded 'compliant' than in the North Island (37.2% compared to 30.5%) (Figure 8).
- In the following territorial authorities all drinking water zones were graded 'compliant' (Figure 9):
  - North Shore
  - Hamilton
  - Lower Hutt
  - Nelson
  - Gore
- Territorial authorities with the largest proportion of drinking water zones graded 'non-compliant/not monitored' were (Figure 9):
  - Kawerau: 100.0%
  - Chatham Islands: 83.3%
  - Opotiki: 78.1%
- There were marked geographical differences within the defined geographic areas (Figure 9).

FIGURE 8: PROPORTION OF DRINKING WATER ZONES BY GRADE AND AREA, 2001 TO 2009–10

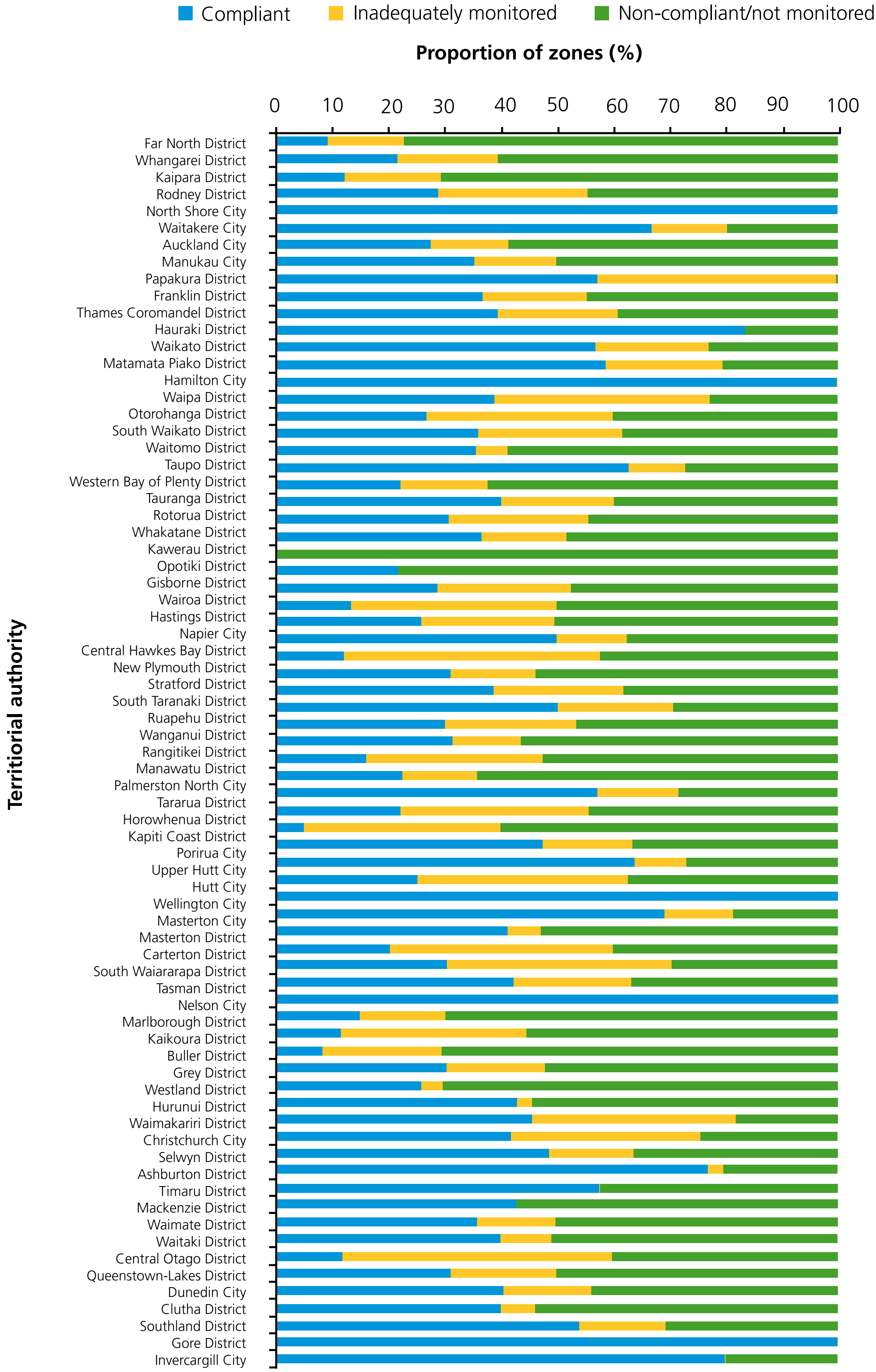


Note: From 2005 to 2006-07 reporting was changed from calendar year to financial year

TABLE 9: PERCENTAGE CHANGE IN THE PROPORTION OF DRINKING WATER ZONES GRADED 'COMPLIANT' BY AREA, 2001 TO 2009–10

	New Zealand		North Island		South Island	
Change		%		%		%
		56.3		36.9		100.8
Increase	Territorial Authority	%	Territorial Authority	%	Territorial Authority	%
	Waitaki	1660.0	Western Bay of Plenty	944.4	Waitaki	1660.0
	Clutha	1000.0	South Taranaki	925.0	Clutha	1000.0
	Dunedin	956.3	Manawatu	781.4	Dunedin	956.3
Decrease						
	Horowhenua	-89.0	Horowhenua	-89.0	Buller	-54.2
	Central Hawke's Bay	-60.6	Central Hawke's Bay	-60.6	Central Otago	-54.2
	Buller	-54.2	Rangitikei	-52.6	Queenstown-Lakes	-50.0

FIGURE 9: PROPORTION OF DRINKING WATER ZONES BY GRADE AND TERRITORIAL AUTHORITY, 2009–10



4.4.6 Drinking water quality – population exposure

DPSEEA component: Exposure

Definition: Proportion of the population on registered drinking water supplies that are exposed to each grade by geographic area (territorial authority)

Relevance and interpretation:

When the state of the environment is altered ecological and other changes may result. These changes in turn influence factors such as pathogen behaviour, disease transmission pathways, exposures and downstream health effects.

Water-borne illnesses can occur when humans ingest or come into contact with water that contains pathogenic organisms. Pathogens can enter water supplies from human and animal wastes. Both surface- and ground- waters (rain, rivers, lakes, aquifers etc) can become contaminated via inadequately treated wastewater, animal manure, runoff from land and urban environments. Treatment plants can be used to remove, or inactivate, pathogens in the water. However, should the source of an untreated or inadequately treated drinking water supply become contaminated, the water is likely to be unsafe. In New Zealand, in order to reduce pathogens in wastewater, it is treated before it is discharged in to the environment. However, the extent and effectiveness of the treatment varies. Pathogens can also enter the water from animal manure. This can occur in several ways including runoff as a result of rain washing manure from pasture in to waterways, animals directly defaecating in water and irrigation of dairy shed effluent back onto land (PCE 2012). Contamination of water from animal manure is of particular concern in New Zealand given the predominance of agricultural land use.

Untreated or inadequately treated drinking water contaminated with pathogens presents a significant risk to human health. The presence of *Escherichia coli* in drinking water indicates recent faecal contamination of the water. If *E. coli* is present, there is also a greater risk of pathogens being present. In New Zealand bacteriological compliance of drinking water is determined primarily using *E. coli* monitoring (Ministry of Health 2011). Thus, the presence of *E. coli* can be used as an indicator of the state of drinking water quality.

The overall burden of endemic drinking water-borne gastrointestinal disease in New Zealand has been estimated at 18,000 to 34,000 cases per year (Ball 2007).

There is increasing evidence that climate change-related alterations in temperature, rainfall (including extreme weather events), surface water availability and water quality could affect the burden of water-related diseases (Bates *et al.* 2008; Confalonieri *et al.* 2007; Hambling & Bandaranayake 2012). Bates *et al.* (2008) identify that higher water temperatures and changes in rainfall will affect water quality and exacerbate many forms of water pollution, with negative impacts on ecosystems, human health and water system reliability. Extreme droughts will reduce water flows and levels, increasing concentrations of pathogens from contaminated effluent discharges. Conversely, heavy rainfall can cause microbial contamination of surface water bodies and shallow groundwaters due to polluted surface runoff and discharges of untreated sewage from over-flowing combined sewage systems. This may increase the total microbial load in watercourses and raw water reservoirs (Kistemann *et al.* 2002).

Recent systematic reviews (Cann *et al.* 2012; ECDC 2012; Rizak & Hrudey 2008) have examined the relationships among climate variables, common risk factors, waterborne pathogens and outbreaks of waterborne diseases. The review by the ECDC (2012) reported associations between certain gastrointestinal diseases and air temperature, water temperature and precipitation events. Cann *et al.* (2012) found evidence to suggest that outbreaks of water-borne infectious disease follow extreme water-related climatic events. Contamination of the drinking water supply accounted for 53.7% of outbreaks following extreme water-related weather events. Rizak and Hrudey (2008) also found that heavy rainfall or runoff, as well as treatment process and system changes, are common risk factors for drinking water disease outbreaks.

Below are four main factors to consider when evaluating the relationship between health outcomes and exposure to changes in rainfall, water availability and quality (Confalonieri *et al.* 2007):

- linkages between water availability, household access to improved water, and the health burden due to diarrhoeal diseases;

- the role of extreme rainfall (intense rainfall or drought) in facilitating water-borne outbreaks of diseases through piped water supplies or surface water;
- effects of temperature and runoff on microbiological and chemical contamination of coastal, recreational and surface waters;
- direct effects of temperature on the incidence of diarrhoeal disease.

This indicator evaluates the public health significance of drinking water quality by measuring the proportion of the population served (ie, exposed) by registered drinking water supplies and the microbiological quality of these supplies.

Computation: P_n/P_t*100
Where P_n = population in a grade
P_t = total population in all grades

Data source: Water Information New Zealand (WINZ) database, Ministry of Health

Results:

Temporal trends, 2001 to 2009-10

- In 2009-10, 92.2% of New Zealand's total population was served by registered drinking water supplies, an increase of 4.5% from 2001 (88.2%) (Figure 10).
- Between 2001 and 2009-10, there was an increase in the proportion of the population served by registered drinking water supplies in zones graded 'compliant' (Figure 11; Table 10):

  - New Zealand: 25.9%
  - North Island: 5.9%
  - South Island: 239.8%
- While the proportion graded 'inadequately monitored' and 'non-compliant/not monitored' decreased (Figure 11; Table 10):

  - New Zealand: 'inadequately monitored' (-69.1%), 'non-compliant/not monitored' (-39.7%)
  - North Island: 'inadequately monitored' (-39.2%), 'non-compliant/not monitored' (-23.6%)
  - South Island: 'inadequately monitored' (-84.5%), 'non-compliant/not monitored' (-60.5%)
- There were marked geographical differences within the defined geographic areas.
- Figure 11 shows the variation in proportion of the population served by registered drinking water supplies in zones in each grade for New Zealand and the North and South Islands, 2001 to 2009-10.

Spatial trends, 2009-10

- In 2009-10, 89.1% of New Zealand's population served by registered drinking water supplies in zones were graded 'compliant', 7.1% 'inadequately monitored', and 3.8% 'non-compliant/not monitored' (Figure 11).
- The North Island had a higher proportion of population served by registered drinking water supplies in zones graded 'compliant' than the South Island (90.3% compared to 85.6%) (Figure 11).
- The following territorial authorities had all of their population served by registered drinking water supplies in zones graded 'compliant' (Figure 12):

  - North Shore
  - Hamilton
  - Lower Hutt
  - Nelson
  - Gore

- Territorial authorities with the largest proportion of their population served by registered drinking water supplies in zones graded 'non-compliant/not monitored' were (Figure 12):
  - Kawerau: 100.0%
  - Rangitikei: 67.0%
  - Otorohanga: 58.5%
- There were marked geographical differences within the defined geographic areas (Figure 12).

FIGURE 10: PERCENTAGE OF NEW ZEALAND'S TOTAL POPULATION SERVED BY REGISTERED DRINKING WATER SUPPLIES (BY GRADE) AND NON-REGISTERED DRINKING WATER SUPPLIES, 2001 TO 2009–10

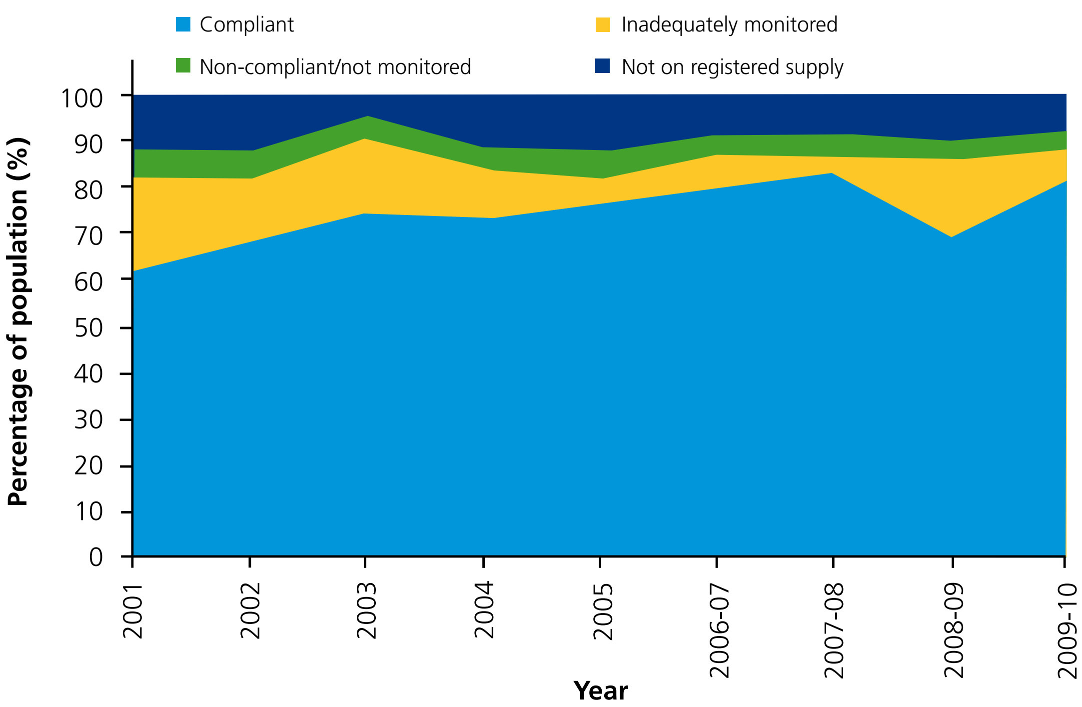
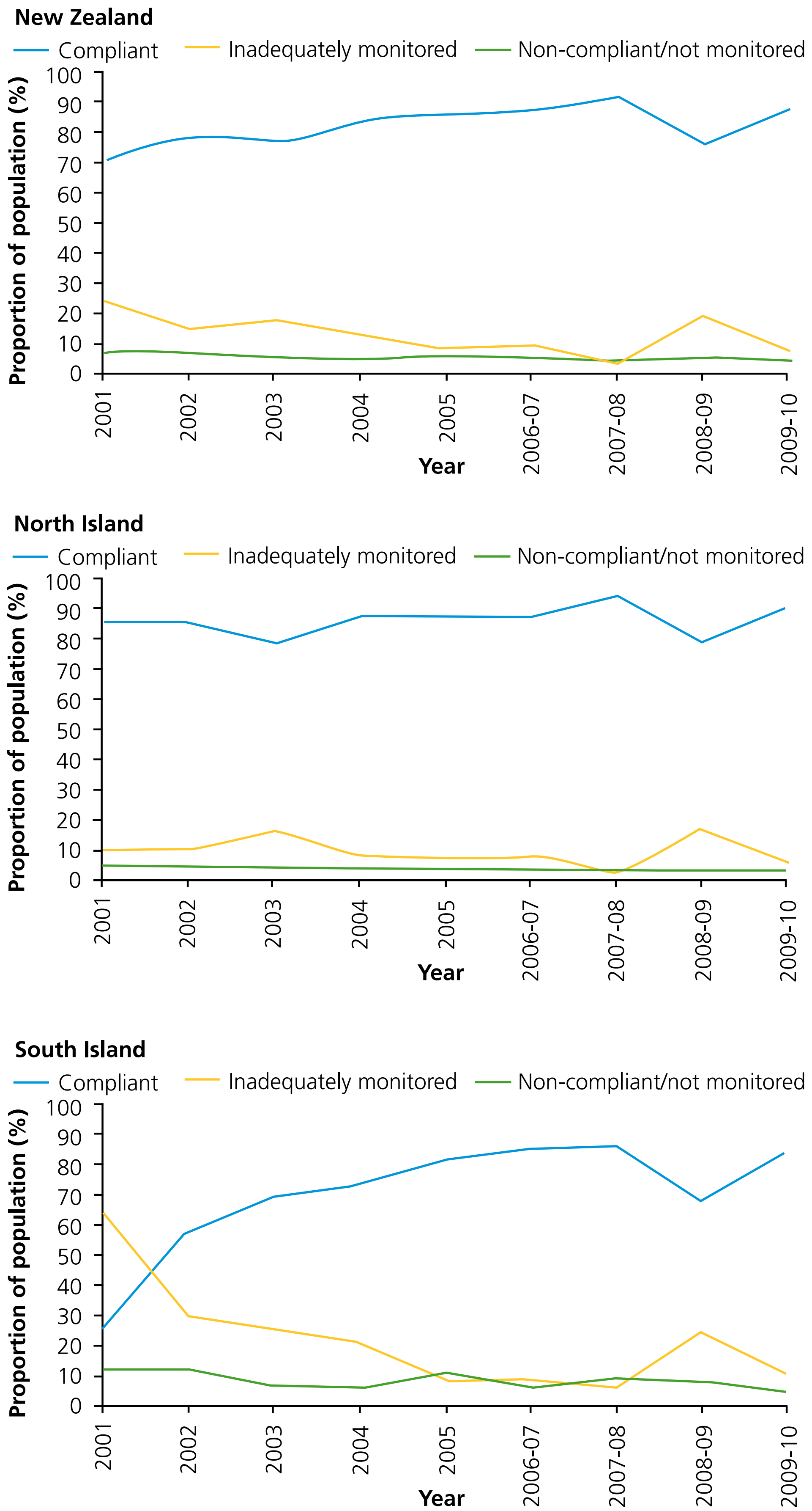


FIGURE 11: PROPORTION OF THE POPULATION ON REGISTERED DRINKING WATER SUPPLIES BY GRADE AND AREA, 2001 TO 2009–10

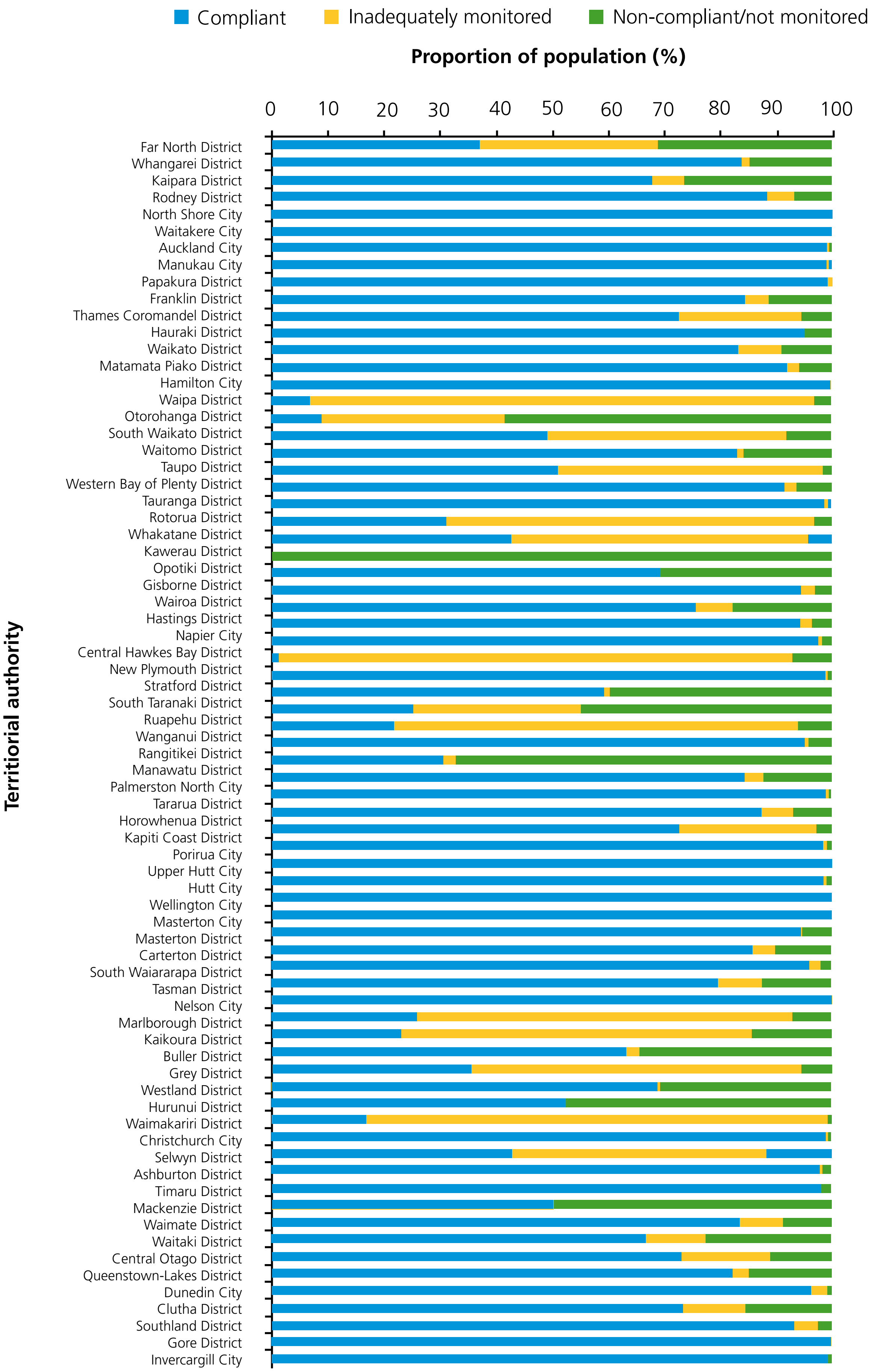


Note: From 2005 to 2006-07 reporting was changed from calendar year to financial year

TABLE 10: PERCENTAGE CHANGE IN THE PROPORTION OF THE POPULATION SERVED BY REGISTERED DRINKING WATER SUPPLIES GRADED 'COMPLIANT' BY AREA, 2001 TO 2009–10

	New Zealand		North Island		South Island	
Change		%		%		%
		25.9		5.9		239.8
Increase	Territorial Authority	%	Territorial Authority	%	Territorial Authority	%
	Waitaki	26,946.3	Western Bay of Plenty	6197.6	Waitaki	26,946.3
	Dunedin	21,554.9	Manawatu	3807.1	Dunedin	21,554.9
	Western Bay of Plenty	6197.6	South Taranaki	2993.5	Invercargill	5637.7
Decrease						
	Central Hawke's Bay	-98.1	Central Hawke's Bay	-98.1	Marlborough	-66.9
	Waipa	-92.4	Waipa	-92.4	Grey	-52.3
	Otorohanga	-75.6	Otorohanga	-75.6	Buller	-24.9

FIGURE 12: PROPORTION OF THE POPULATION ON REGISTERED DRINKING WATER SUPPLIES BY GRADE AND TERRITORIAL AUTHORITY, 2009–10



4.4.7 Salmonellosis burden of disease – incidence

DPSEEA component: Effect

Definition: Salmonellosis notification rate by geographic area (territorial authority)

Relevance and interpretation:
Salmonellosis is one of the most common food-borne illnesses worldwide. It constitutes a major public health burden and represents a significant cost in many countries. In 2011, salmonellosis was the second most common enteric bacterial infection notified in New Zealand with a notification rate of 24.0 per 100,000 population (1056 cases) (ESR 2012).

The majority of salmonellosis is linked to contaminated food, however, it is also a significant cause of water-borne disease associated with environmental sources such as surface and marine water (Haley *et al.* 2009; Wilson & Baker 2009). In developed countries it is possible that climate change could disproportionally increase water-borne disease incidences over food-borne ones as food handling and storage regulations should help counter impacts of increased temperatures.

Salmonella is transmitted mainly through consumption of contaminated food. An overall assessment of the aetiology of salmonellosis in the New Zealand domestic setting (Wilson & Baker 2009) concluded that:

- contaminated food: 'very likely' to be 'the majority cause' (ie, > 50% of cases)
- person-to-person: 'likely' to be a 'moderate cause' (ie, between 10–30% of cases)
- direct animal contact: 'likely' to be a 'minor cause' (ie, < 10% of cases)
- contaminated domestic water: 'very likely' to be a 'minor cause' (ie, < 10% of cases)
- recreational water exposure: 'very likely' to be a 'minor cause' (ie, < 10% of cases)
- contaminated environments: 'very likely' to be a 'minor cause' (ie, < 10% of cases)

The role of food vehicles in the New Zealand setting was also assessed (Wilson & Baker 2009) and concluded that:

- poultry: 'very likely' to be at least a moderate cause (ie, between 10–30% or higher of all cases)
- pig meat: 'likely' to be at least a 'moderate cause' (ie, between 10–30% or higher of all cases)
- beef: 'likely' to be at least a 'moderate cause' (ie, between 10–30% or higher of all cases)
- meat in general (excluding poultry and fish): 'likely' to be at least a 'moderate cause' (ie, between 10–30% or higher of all cases)
- eggs: 'likely' to be a 'minor cause' (ie, < 10% of food-borne cases)
- sheep meat: 'likely' to be a 'minor cause' (ie, < 10% of food-borne cases)
- dairy products: 'likely' to be a 'minor cause' (ie, < 10% of food-borne cases)
- fresh produce: 'likely' to be a 'minor cause' (ie, < 10% of food-borne cases)

IPCC report chapters (Confalonieri *et al.* 2007; Hennessy *et al.* 2007) state that several studies have confirmed and quantified the effects of high temperatures on common forms of food poisoning, such as salmonellosis (D'Souza *et al.* 2004; Kovats *et al.* 2004; Fleury *et al.* 2006). These studies found an approximately linear increase in reported cases with each degree increase in weekly or monthly temperature. Temperature is much less important for the transmission of *Campylobacter* (Kovats *et al.* 2005; Louis *et al.* 2005; Tam *et al.* 2006). Warmer temperatures and increased rainfall variability are likely to increase the intensity and frequency of food-borne (D'Souza *et al.* 2004) and water-borne (Hall *et al.* 2002) diseases in both Australia and New Zealand.

Computation: N/P *100,000
Where N = number of cases
P = total population

Note: Number of cases = includes confirmed and probable cases that had not traveled overseas during the incubation period for the disease and had no prior history of travel that could account for their infection.

Percentage change in rate:

$$(R_{t1} - R_{t0}) / R_{t0} * 100$$

Where R_{t1} = rate at time 1

R_{t0} = rate at time 0

Data source: National notifiable disease surveillance system (EpiSurv), ESR

Results:

Temporal trends, 2001 to 2010

- Between 2001 and 2010, there was a general decrease in the salmonellosis notification rate (Figure 13; Table 11):
  - New Zealand: -58.5% (54.6 to 22.6 per 100,000 population)
  - North Island: -65.0% (50.8 to 17.8)
  - South Island: -42.6% (66.6 to 38.2)
- The majority (87.5%) of territorial authorities showed a decrease in the rate of salmonellosis.
- In New Zealand, the salmonellosis notification rate shows a seasonal pattern with highest rates during the summer months (Figure 14).
- There were marked geographical differences within the defined geographic areas.
- Figure 14 shows the variation in the monthly salmonellosis notification rates between 2001 and 2010 for New Zealand and the North and South Islands.

Spatial trends, 2010

- In 2010, the salmonellosis notification rate was (Figure 13):
  - New Zealand: 22.6 per 100,000 (range: 6.2 to 108.9)
  - North Island: 38.2 per 100,000 (range: 6.2 to 64.2)
  - South Island: 17.8 per 100,000 (range: 17.6 to 108.9)
- There were marked geographical differences within the defined geographic areas (Figure 15).
- Territorial authorities with the highest salmonellosis rates were (Figure 15):
  - Clutha: 108.9 per 100,000
  - Gore: 97.6 per 100,000
  - Central Otago: 87.9 per 100,000
- Territorial authorities with the lowest rates were (Figure 15):
  - Palmerston North: 6.2 per 100,000
  - Hamilton: 9.8 per 100,000
  - Papakura: 10.0 per 100,000

FIGURE 13: SALMONELLOSIS NOTIFICATION RATE BY AREA, 2001 TO 2010

TABLE 11: PERCENTAGE CHANGE IN THE SALMONELLOSIS NOTIFICATION RATE BY AREA, 2001 TO 2010

	New Zealand		North Island		South Island	
Rate change		%		%		%
		-58.5		-65.0		-42.6
Rate increase	Territorial Authority	%	Territorial Authority	%	Territorial Authority	%
	Kawerau	108.6	Kawerau	108.6	Queenstown-Lakes	103.3
	Queenstown-Lakes	103.3	Gisborne	59.0	Central Otago	62.1
	Central Otago	62.1	Otorohanga	29.0	Westland	20.0
Rate decrease						
	Buller	-90.1	Wanganui	-88.7	Buller	-90.1
	Wanganui	-88.7	Carterton	-88.4	Hurunui	-81.7
	Carterton	-88.4	Stratford	-88.3	Nelson	-80.7

FIGURE 14: SALMONELLOSIS NOTIFICATION RATE BY MONTH, YEAR AND AREA, 2001 TO 2010

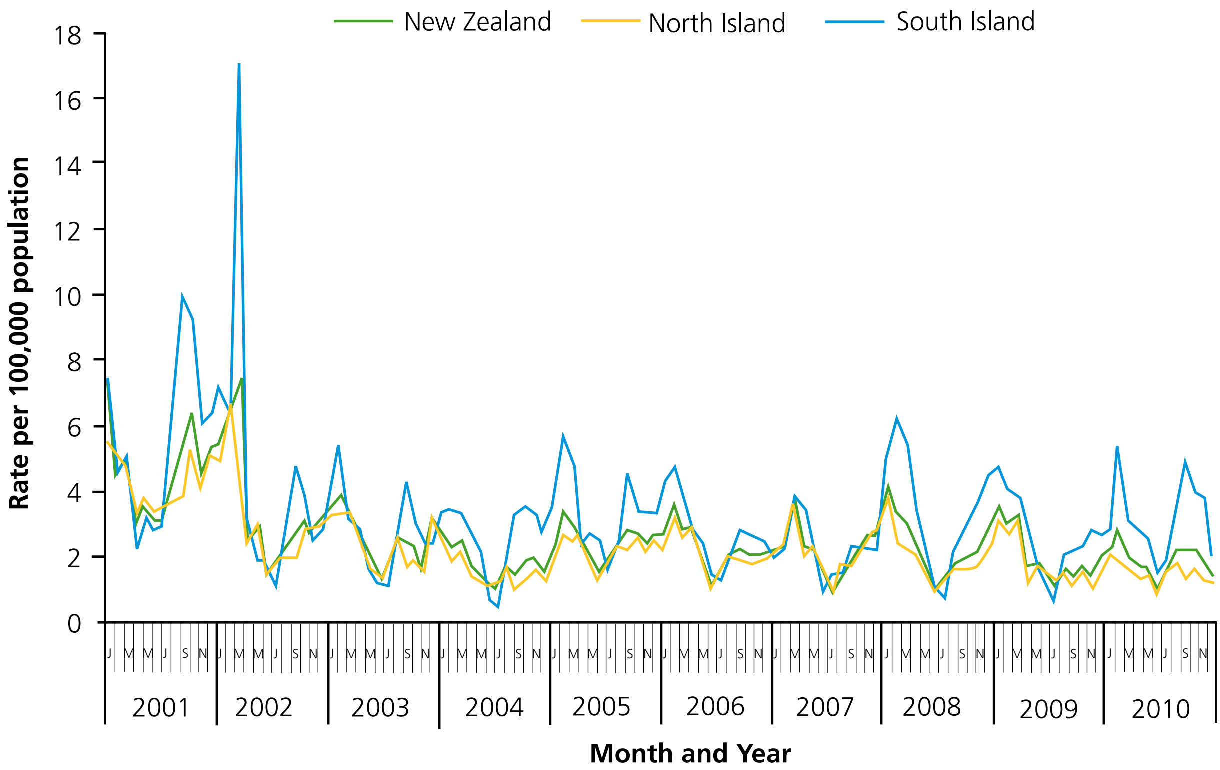
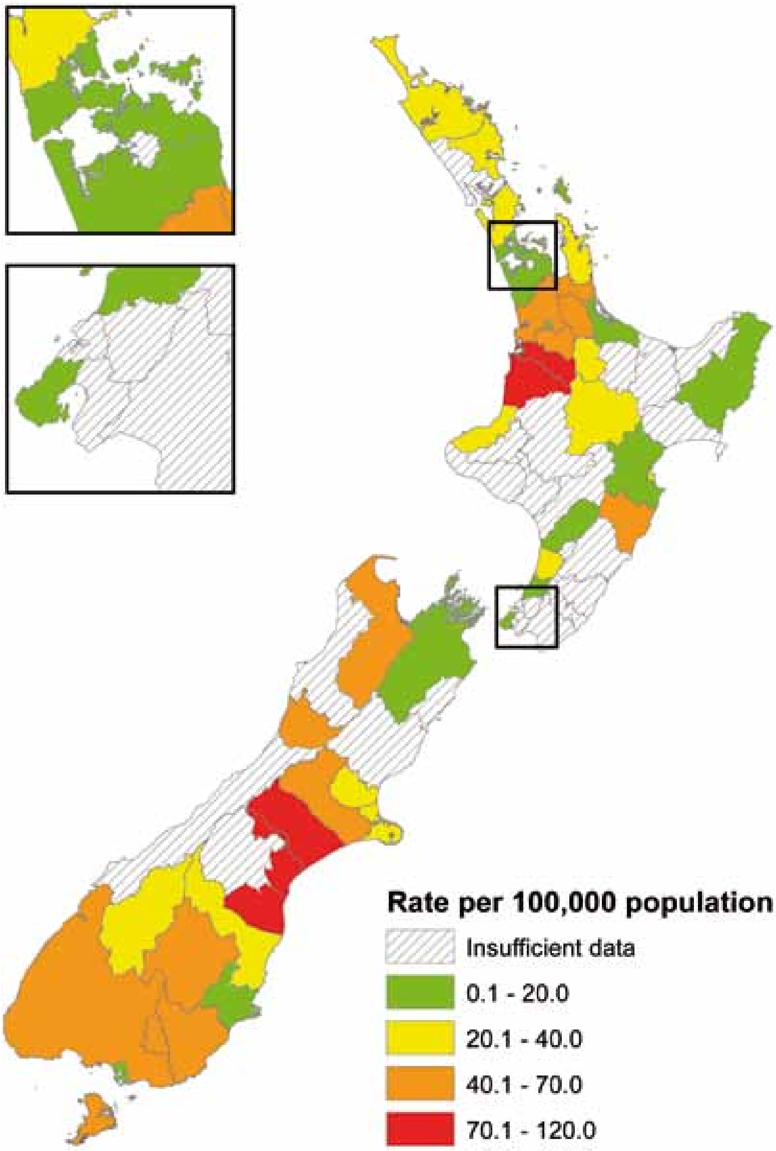


FIGURE 15: SALMONELLOSIS NOTIFICATION RATE BY TERRITORIAL AUTHORITY, 2010



Rates have not been calculated where fewer than 5 cases were notified. Calculating population rates from fewer than 5 cases produces unstable rates.

Refer to Appendix 1 for a reference map of New Zealand featuring territorial authorities.

5. Resources

Hambling T, Weinstein P, Slaney D. (2011) A review of frameworks for developing environmental health indicators for climate change and health. International Journal of Environmental Research & Public Health 8(7):2854–28 http://www.mdpi.com/1660-4601/8/7/2854/

Hambling T, Weinstein P, Slaney D. (2010) Climate Change Environmental Health Indicators: devising a tool to measure and monitor human health vulnerability and the effectiveness of interventions for climate variability and change. International Climate Change Adaptation Conference, 29 June–1 July 2010, Gold Coast, Queensland, Australia http://www.nccarf.edu.au/conference2010/archives/265

Hambling T. & Slaney D. (2007) Environmental Health Indicators for New Zealand: Annual Report 2007. Institute of Environmental Science & Research Ltd, Porirua, New Zealand http://www.surv.esr.cri.nz/ehi/ehi_reports.php

Related websites

New Zealand
http://www.surv.esr.cri.nz/ehi/ehi.php

Europe
http://ec.europa.eu/health/indicators/other_indicators/environment/index_en.htm

http://www.euro.who.int/en/what-we-do/data-and-evidence/environment-and-health-information-system-enhis/

http://www.who.int/globalchange/en/index.html

United States
http://ephtracking.cdc.gov/showIndicatorsData.action

http://ephtracking.cdc.gov/showClimateChangeLanding.action

References

Aron J and Patz J. (2001) Ecosystem Change and Public Health: A Global Perspective. The Johns Hopkins University Press, Baltimore, MD, USA.

Ball A. (2007) Estimation of the Burden of Disease in New Zealand: Preliminary Report. Institute of Environmental Science & Research, Porirua, New Zealand.

Bates B, Kundzewicz Z, Wu S, and Palutikof J (Eds). (2008) Climate Change and Water. Technical Paper VI of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, Switzerland.

Bongaarts J. (1992) Population growth and global warming. Population and Development Review 18(2):299–319.

Briggs D. (1999) Environmental Health Indictors: Framework and Methodologies WHO/SDE/OEH/99.10. World Health Organization, Geneva, Switzerland.

Briggs D. (2003) Making a Difference: Indicators to Improve Children's Environmental Health. World Health Organization. Available online: http://www.who.int/phe/children/en/cehindic.pdf (accessed on 2 April 2008).

Cann K, Thomas D, Salmon R, Wyn-Jones A, and Kay D. (2012) Extreme water-related weather events and waterborne disease. Epidemiology and Infection, Available on CJO 2012 doi: 10.1017/S0950268812001653.

Confalonieri U and McMichael A. (2006) Global environmental change and human health: Science plan and implementation strategy. Earth System Science Partnership Report 4:1–79.

Confalonieri U, Menne B, Akhtar R, Ebi K, Hauengue M, Kovats R, Revich B, and Woodward A. (2007) Human health. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [ML Parry, OF Canziani, JP Palutikof, PJ van der Linden and CE Hanson (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA:391–431.

Corvalán C, Briggs D, and Zielhius G. (2000) Decision-Making in Environmental Health: From Evidence to Action. E & FN Spon, London, United Kingdom.

D'Souza R, Becker N, Hall G, and Moodie K. (2004) Does ambient temperature affect foodborne disease? Epidemiology 15(1):86–92.

ECDC (European Centre for Disease Prevention and Control). (2012) Assessing the Potential Impacts of Climate Change on Food- and Waterborne Diseases in Europe. ECDC, Stockholm.

Ebi K, Smith J, and Burton I. (2005) Integration of Public Health with Adaptation to Climate Change: Lessons Learned and New Directions. Taylor & Francis, London, United Kingdom.

ESR (The Institute of Environmental Science and Research Ltd). (2012) Notifiable and other diseases in New Zealand: annual report 2011, Porirua, New Zealand.

Fleury M, Charron D, Holt J, Allen O, and Maarouf A. (2006) A time series analysis of the relationship of ambient temperature and common bacterial enteric infections in two Canadian provinces. International Journal of Biometeorology 50(6):385–391.

Haley B, Cole D, and Lipp E. (2009) Distribution, diversity, and seasonality of waterborne Salmonellae in a rural watershed, Applied and Environmental Microbiology 75(5):1248–1255.

Hall G, D'Souza R, and Kirk M. (2002) Food-borne disease in the new millennium: out of the frying pan and into the fire? Medical Journal of Australia 177(2):614–618.

Hambling T and Bandaranayake D. (2012) Climate change and waterborne diseases in New Zealand and the role of primary care in the early detection of common source waterborne disease outbreaks. New Zealand Public Health Surveillance Report: December 2012 10(4). Institute of Environmental Science & Research Ltd, Porirua, New Zealand.

Hambling T and Slaney D. (2007) Environmental Health Indicators for New Zealand: Annual Report 2007. Institute of Environmental Science & Research Ltd, Porirua, New Zealand http://www.surv.esr.cri.nz/ehi/ehi_reports.php

Hambling T, Weinstein P, and Slaney D. (2011) A review of frameworks for developing environmental health indicators for climate change and health. International Journal of Environmental Research & Public Health 8(7):2854–28 http://www.mdpi.com/1660-4601/8/7/2854/

Hennessy K, Fitzharris B, Bates B, Harvey N, Howden S, Hughes L, Salinger J, and Warrick R. (2007) Australia and New Zealand. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [ML Parry, OF Canziani, JP Palutikof, PJ van der Linden and CE Hanson (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA:507–540.

Hunter L. (2000) The environmental implications of population dynamics. RAND, California & Virginia, USA.

IPCC (Intergovernmental Panel on Climate Change). (2007) Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [S Solomon, D Qin, M Manning, Z Chen, M Marquis, KB Averyt, M Tignor and HL Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Jones K, Patel N, Levy M, Storeygard A, Balk D, Gittleman J, and Daszak P. (2008) Global trends in emerging infectious diseases. Nature 451:990–993.

Kjellström T and Corvalán C. (1995) Framework for the development of environmental health indicators. World Health Statistics Quarterly 48:144–154.

Kistemann T, Classen T, Koch C, Dangendorf F, Fischeder R, Gebel J, Vacata V, and Exner M. (2002) Microbial load of drinking water reservoir tributaries during extreme rainfall and runoff. Applied and Environmental Microbiology 68(5):2188–2197.

Kovats R, Edwards S, Charron D, Cowden J, D'Souza R, Ebi K, Gauci C, Gerner-Smidt P, Hajat S, Hales S, Pezzi G, Kriz B, Kutsar K, McKeown P, Mellou K, Menne B, O'Brien S, van Pelt W, and Schmid H. (2005) Climate variability and campylobacter infection: an international study. International Journal of Biometeorology 49(4):207–214.

Kovats R, Edwards S, Hajat S, Armstrong B, Ebi K, and Menne B. (2004) The effect of temperature on food poisoning: time series analysis in 10 European countries. Epidemiology and Infection 132(3):443–453.

Leisnham P and Slaney D. (2009) Invited review—Urbanization and the increasing risk from mosquito-borne diseases: linking human well-being with ecosystem health. In: Focus on Urbanization Trends [L De Smet (ed)]. Nova Publishers, New York, NY, USA: 47–82.

Louis V, Gillespie I, O'Brien S, Russek-Cohen E, Pearson A, and Colwell R. (2005) Temperature-driven Campylobacter seasonality in England and Wales. Applied Environmental Microbiology 71(1):85–92.

Ministry for the Environment. (2012) New Zealand's Greenhouse Gas Inventory 1990–2010. Ministry for the Environment, Wellington, New Zealand.

Ministry of Health. (2009) List of diseases that are notifiable to the Medical Officer of Health. Available online: http://www.health.govt.nz/our-work/diseases-and-conditions/notifiable-diseases (accessed on 20 April 2010).

Ministry of Health. (2011) Annual report on drinking-water in New Zealand 2009–2010. Ministry of Health, Wellington, New Zealand.

NIWA (National Institute of Water and Atmospheric Research). (2008) Climate change: projections for New Zealand. NIWA National Climate Centre, Wellington, New Zealand.

NIWA (National Institute of Water and Atmospheric Research). (2012a) Past climate variations over New Zealand. Available at http://www.niwa.co.nz/our-science/climate/information-and-resources/clivar/pastclimate#nzat [accessed 10 July 2012].

NIWA (National Institute of Water and Atmospheric Research). (2012b) Climate change scenarios for New Zealand. Available at http://www.niwa.co.nz/our-science/climate/information-and-resources/clivar/scenarios [accessed 10 April 2012].

Patz J, Campbell-Lendrum D, Holloway T, and Foley J. (2005) Impact of regional climate change on human health. Nature 438:310–317.

PCE (Parliamentary Commissioner for the Environment). (2012) Water quality in New Zealand: understanding the science. PCE, Wellington, New Zealand.

Rizak S and Hrudey S. (2008) Drinking-water safety – challenges for community-managed systems. Journal of Water and Health 6 Suppl 1:33–41.

Salinger M and Mullan A. (1999) New Zealand Climate: temperature and precipitation variations and their links with atmospheric circulation 1930–1994. International Journal of Climatology 19(10):1049–1071.

Statistics New Zealand. (2004) National Population Projections 2004 (base)–2051. Available at http://www.stats.govt.nz/browse_for_stats/population/estimates_and_projections/NationalPopulationProjections_HOTP04-51/Commentary.aspx [accessed 17 June 2012].

Tam C, Rodrigues L, O'Brien S, and Hajat S. (2006) Temperature dependence of reported Campylobacter infection in England, 1989–1999. Epidemiology and Infection 134(1):119–125.

Wilson N and Baker M. (2009) A systematic review of the aetiology of salmonellosis in New Zealand. New Zealand Food Safety Authority, Wellington, New Zealand.

World Health Organization. (2001) Monitoring Health Impacts of Climate Change in Europe: Meeting Report: EUR/01/502 6360. World Health Organization, London, United Kingdom.

World Health Organization. (2010) Climate, Environment and Health Action Plan and Information System: Work Package 5: policy monitoring and assessment. World Health Organization, Bonn, Germany.

Appendix 1

Reference map of New Zealand featuring territorial authorities

	Cities		Districts		
1	Waitakere	16	Far North	45	Wanganui
2	North Shore	17	Whangarei	46	Rangitikei
3	Auckland	18	Kaipara	47	Manawatu
4	Manukau	19	Rodney	48	Tararua
5	Hamilton	20	Papakura	49	Horowhenua
6	Napier	21	Franklin	50	Kapiti Coast
7	Palmerston North	22	Thames-Coromandel	51	Masterton
8	Porirua	23	Hauraki	52	Carterton
9	Upper Hutt	24	Waikato	53	South Wairarapa
10	Lower Hutt	25	Matamata-Piako	54	Tasman
11	Wellington	26	Waipa	55	Marlborough
12	Nelson	27	Otorohanga	56	Kaikoura
13	Christchurch	28	South Waikato	57	Buller
14	Dunedin	29	Waitomo	58	Grey
15	Invercargill	30	Taupo	59	Westland
		31	Western Bay of Plenty	60	Hurunui
		32	Tauranga	61	Waimakariri
		33	Rotorua	62	Selwyn
		34	Whakatane	63	Ashburton
		35	Kawerau	64	Timaru
		36	Opotiki	65	Mackenzie
		37	Gisborne	66	Waimate
		38	Wairoa	67	Waitaki
		39	Hastings	68	Central Otago
		40	Central Hawke's Bay	69	Queenstown-Lakes
		41	New Plymouth	70	Clutha
		42	Stratford	71	Southland
		43	South Taranaki	72	Gore
		44	Ruapehu	73	Chatham Islands