

## National assessments of health impacts of climate change: a review

R.S. Kovats,<sup>1</sup> B. Menne,<sup>2</sup> M.J. Ahern,<sup>1</sup> J.A. Patz<sup>3</sup>

### Introduction

Previous chapters have shown that climate change represents a serious environmental threat over the coming century. The public health community has a responsibility to provide policy-makers with evidence of the potential impacts of climate change on human population health. Policy-makers are obliged to respond to this risk even in the face of scientific uncertainties. The public health community has established methods for assessing the risks to health for a population. WHO defines health impact assessment as “a combination of procedures, methods and tools by which a policy, project or hazard may be judged as to its potential effects on the health of a population, and the distribution of those effects within the population” (1, 2). Despite recent advances in the methodology for health impact assessment, the greater goal of integration into mainstream policy-making has yet to be achieved. This objective is a long way off in both developed and developing countries.

Global climate change presents many unique problems for health impact assessment. It is a highly diffuse global exposure for which very limited information (in the form of climate projections) is available at local or national level. For many health impacts this is not an immediate problem but one that will develop over decades or longer. Action is needed now to avert the worst impacts through the reduction of greenhouse gas emissions. Further, guidance is required now on policies to enhance the capacity to deal with climate change (chapter 12). Health impact assessments typically refer to impacts in the next 10 to 20 years, rather than the 50 to 100 year time-scale of climate change projections and the assessments of impacts in other sectors.

Global assessments have been undertaken by the Intergovernmental Panel on Climate Change (IPCC) in the Second and Third Assessment Reports (3, 4). Such global assessments make general statements about the types of impacts that climate change may have upon human health outcomes. In theory, national assessments should provide the global assessments with important information about regional and local vulnerability. In practice, this has proved difficult to achieve for a variety of reasons that will be discussed below. Assessments should be country driven and reflect local environmental and health priorities. Where sufficient resources have been available, there has been a preference to include

---

<sup>1</sup> London School of Hygiene and Tropical Medicine, London, England.

<sup>2</sup> World Health Organization Regional Office for Europe, European Centre for Environment and Health, Rome, Italy.

<sup>3</sup> Johns Hopkins University, Baltimore, MD, USA.

some quantification of health impacts in future decades. However many assessments rely on a qualitative assessment of the available literature.

Several agencies have produced guidelines on assessing the impacts of climate change (5, 6). These are seen as inadequate for addressing impacts in social systems and outcomes such as human health that are more complex and context-specific. Health impact assessments must use the best available scientific evidence to inform policy decisions. In 1999 the European Ministerial Conference on Environment and Health recommended countries to:

- develop capacities to undertake national health impact assessments with the aim of identifying the vulnerability of populations and subgroups. Ensure the necessary transfer of know-how among countries;
- carry out ongoing reviews of the social, economic and technical prevention, mitigation and adaptation options available to reduce the adverse impacts of climate change and stratospheric ozone depletion on human health.

This chapter reviews national assessments that have addressed climate change impacts on human population health in some detail, with particular reference to:

- methods and tools used
- main findings
- integration with other climate assessments (in non-health sectors and other geographical regions)
- assessments of adaptation (what is likely and what is recommended).

## **Health impact assessments: key concepts and methods**

Health impact assessments (HIA) are undertaken for a variety of purposes and under a variety of circumstances. The purpose of the health impact assessment will therefore determine its scope, form and content. Health impact assessments are multi-disciplinary by necessity and bring together a range of methods and tools: policy appraisal, evidence-based risk assessment and environmental impact assessment (7). The common elements of health impact assessments include:

- integrated assessment of impacts, i.e. not concentrating on single risk factors and disease outcomes (a holistic view of health);
- relate to policies and projects outside the health sector;
- multidisciplinary process;
- provide information for decision-makers, therefore designed with needs of decision-makers in mind;
- quantification of the expected health burden due to an environmental exposure in a specific population.

There is growing consensus that systematic assessments of health effects are needed to inform the development of policies and to include health in the agendas of other sectors—such as water, food, housing, trade, etc. Legislation and legally binding agreements at the international level now make provision for HIA in policy-making. Anthropogenic climate change as an exposure is different to other types of hazard and new methods and tools need to be developed.

Bernard and Ebi (8) identify a critical distinction between climate change impact assessment and traditional environmental health quantitative risk assessment (QRA). The primary assumptions underlying QRA are no longer applica-

ble. Climate change is not a defined exposure to a specific agent (the pollutant) that causes an adverse health outcome to identifiable exposed populations. Climate change is associated with a range of climate and weather exposures that are mediated in complex fashion through a range of mechanisms. The challenges that this poses for scientific assessment are described in detail in chapter four. If the impacts of climate change are to be measured quantitatively, then existing population-based methodologies such as Comparative Risk Assessment (CRA) have to be adapted and applied in a flexible manner, with appropriate description of uncertainties (see chapter seven).

Health impact assessment often is part of a wider prospective environmental impact assessment of a specific project or development (mezzosocial focus) for which specific tools are available. Climate change assessments operate at the macrosocial level because the impacts on an entire population (country or region) are considered. This would be similar to the evaluation of a particular policy, e.g. energy policy. Such assessments should include reports of current health status using standard epidemiological indicators, e.g. mortality rates, etc. Health impact assessment of government policy has been implemented in Canada (7). The methods used a framework of questions to guide decision-makers in considering factors that influence population health for the following key areas: employment and economy; education and skills; environment and safety; programmes and services. Other examples of broad policy related assessments are the quantification of the health impacts of traffic related air pollution in three European countries (9), and the estimation of health costs for different fuel cycles—such as coal, nuclear (ExternE project (10)).

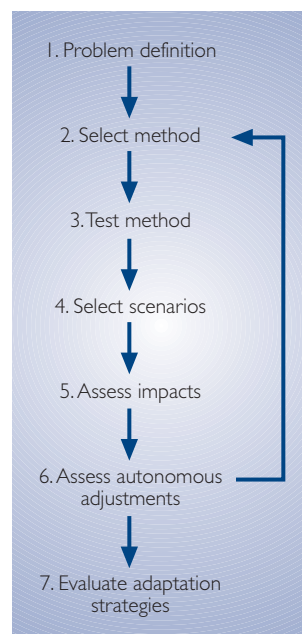
## Methods for climate-change impact assessments

Approaches to climate impact assessment have evolved rapidly since climate change became a policy concern in the 1980s. Methods and tools have been developed primarily for climate assessments for biophysical impacts for either economic (agriculture, forestry) or intrinsic value (biodiversity). Impact assessment in social systems has addressed the impact of weather disasters and the implications for the insurance industry. The IPCC has produced methodological guidelines in order to ensure standardization in methods across sectors and disciplines (5, 6, 11), but these have limited use for assessing impacts in socioeconomic or human systems. The IPCC guidelines focus on impacts rather than adaptive measures (or adaptive capacity) as adaptive responses vary greatly between countries and are less easily described in terms of generic methods (12).

Figure 9.1 illustrates the framework first described in the IPCC guidelines (5) and expanded upon by Parry and Carter (6). The methodological approach is rigidly top down. That is, scenarios of climate change (generated by global climate models) are used as input to large-scale biophysical models. Current methods now incorporate future projections of populations and GDP together with storylines regarding the future worlds in which the impacts of climate change will be experienced (11, 13).

The first specific guidelines for health appeared in the UNEP Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies (14). The aim of the UNEP country studies programme was to improve the methods for assessing climate change impacts in developing countries or countries with economies in transition. One of the stated aims was to test the methods described in the Handbook on Methods for Climate Change Impact and Adaptation

**FIGURE 9.1 Steps in climate change impact and adaptation assessment.** Source: reproduced from reference 6.



Assessment. The UNEP country studies programme ended in 2000 with completed studies on four countries: Antigua and Barbuda, Cameroon, Estonia and Pakistan (15). Only the Cameroon and Antigua and Barbuda studies addressed health. Several problems were found with the guidelines: in particular, the 100-year time frame for climate change projections had little practical relevance. Further, the methods described in the Handbook were found to rely too much on health (and other) data that were not available in either Cameroon or Antigua and Barbuda. The lack of data with which to generate and validate the climate-health models is cited often as a significant limitation. However, even if such data are available, the development and interpretation of such models creates many difficulties.

There are limitations with the scenario driven predictive modelling approach to assessing health impacts at the national level. A major problem is the mismatch between the spatial and temporal scale of environmental factors that affect health (local concentrations of air pollutants, focal vector distributions) and the scenarios of future climate change (global climate model grid boxes). Given the limits of climate scenarios (16), it may be appropriate to use analogue scenarios of changes in temperature and precipitation that can provide important information regarding the relative contribution of climate and non-climate factors to the burden of disease.

Health impact assessments include an evaluation of the epidemiological evidence base for the causal relationships on which to base future projections. Some discussion is necessary of the current knowledge of the local relationships between climate variability and disease, with particular attention to the plausible mechanisms by which climate/weather affect health; such relationships are generally population specific. If such information is not available in the published literature, this type of analysis could be part of the assessment.

For the United States of America's health impact assessment, the target questions were widened to address current vulnerability to climate-sensitive diseases and weather extremes:

- what are current environmental stresses and issues for the United States that will form a backdrop for potential additional impacts of climate change?
- how might climate variability and change exacerbate or ameliorate existing problems?
- what are the priority research and information needs that can better prepare policy-makers to reach wise decisions related to climate variability and change?
- what research is the most important over the short-term? Over the long term?
- what coping options exist that can build resilience into current environmental stresses, and also possibly lessen the impacts of climate change?

The United States' assessment was able to make use of a considerable amount of published literature on health relationships. Other countries, particularly developing countries, are unlikely to have the background information available. Assessments have thus used a variety of methods to estimate future impacts on health. These are discussed in more detail below.

## Review of national health assessments

This chapter reviews national assessments on the potential health impacts of climate change that were published before mid 2002. There is some difficulty in defining what constitutes a national impact assessment. Many countries have addressed health impacts in their national communications to the United Nations Framework Convention on Climate Change (UNFCCC), however, few of these constitute a formal impact assessment. Our criteria for including a report are:

- assessment at national level or below (excluded international assessments such as IPCC reports)
- undertaken for the Ministry of Health or Environment, i.e. central or regional government
- explicitly addresses global climate change and human health
- involves some formal methods of assessment, e.g. systematic literature review or modelling.

Table 9.1 lists the national assessments, the majority from developed countries, which fit these criteria. A few large studies have been undertaken as part of a comprehensive, multi-sectoral assessment, such as in the United States and Canada. In contrast, European countries have conducted few assessments: only the United Kingdom and Portugal have conducted comprehensive assessments. Assessments in developing countries have been undertaken only under the auspices of donor-funded capacity building initiatives. It is possible that sub-national or local assessments have been undertaken for climate change impacts that address health but the authors have been unable to find them. The majority of these studies are in the grey literature and not widely available.

Several types of assessments have been undertaken. At one level there is a basic review of the types of potential impacts with little evaluation of evidence that they are likely to occur. Such assessments can be undertaken with few resources but provide very limited information. At another level, comprehensive well-funded and well-supported assessments are undertaken. For example, in the United States assessment, health was one of 5 sectoral assessments, and included in 16 regional assessments and the overall synthesis report. This assessment involved stakeholder participation and extensive consultation and peer review (8).

**TABLE 9.1 National Climate Health Impact Assessments.**

Country	Reference	Methods	Areas of concern for climate change
Antigua and Barbuda	O'Marde & Michael, 2000 (17)	Forecasting by analogy.	Coastal flooding due to sea level rise, impacts of hurricanes, increases in dengue transmission.
Australia	NHMRC, 1991 (18)	Expert judgement.	None specified, focuses on adaptation.
Australia	McMichael et al., 2002 (19)	Predictive modelling.	No impact on heat stress. Changes in distribution of malaria vectors. Increases in diarrhoeal disease.
Cameroon	UNEP/ Ministry of Environment and Forestry, Cameroon, 1998 (20)	Expert judgement.	Possible increases in cholera, malaria, yellow fever, meningitis, malnutrition.
Canada	Duncan et al., 1997 (21)	Literature review, expert judgement, predictive modelling.	Increases in heat-related deaths, risk that vector-borne diseases may extend north into Canada, environmental refugees.
Fiji	de Wet & Hales, 2000 (22)	Literature review, predictive modelling.	Increases in dengue, diarrhoeal disease.
Japan	Ando, 1993 (23)	Literature review.	Heat stress and photochemical air pollution may increase. Malaria.
Japan	Ando et al. 1998 (24)	Literature review, expert judgement, predictive modelling.	Heat stress. Malaria.
Kiribati	Taeuea, T. et al. 2000 (25)	Literature review, predictive modelling.	Increases in dengue, diarrhoeal disease and ciguatera fish poisoning.
Netherlands	Martens, 1996 (26)	Literature review, expert judgement.	Heat stress, flooding.
New Zealand	Woodward et al. 2001 (27)	Literature review, predictive modelling.	Risk of introduction of mosquito vector species into north island.
Panama	Sempris, E. & Lopez, R. eds. 2001.—ANAM/UNDP (28)	Quantitative assessment of climate with diarrhoeal illness and influenza.	Potential increases in diarrhoeal disease in vulnerable areas.
Portugal	Casimiro, E. & Calheiros, J.M. 2002 (29)	Extensive literature review, predictive modelling, identified populations at risk.	Heat-related deaths, food and water borne diseases, air pollution effects, vector and rodent borne disease.
Sri Lanka	Ratnasari, J. 1998 (30)	Expert judgement, predictive model.	Malaria.
St Lucia	St Lucia National Communication (31)	Assessment of current burden of climate sensitive diseases.	Drought and diarrhoeal disease.
United Kingdom	CCIRG. 1996 (32)	Literature review.	Heat-related deaths and extreme events.
United States	Dept of Health, 2002 (33)	Expert judgement, predictive modelling	Thermal stress, air pollution, flooding, water borne disease.
	USEPA, 1989 (34)	Literature review, some modelling.	Increases in vector-borne diseases. See table 9.3
	Patz et al., 2000 (35)	Literature review, expert judgement.	
	+various documents		
Zambia	Phiri, J. & Msiska, D. 1998 (36)	Expert judgement.	Malaria, schistosomiasis, water-borne diseases and malnutrition.

The assessments do not consistently report their conclusions regarding future risks to health. The outcomes listed in Table 9.1 refer to likely impacts of climate change on that country's health addressed within the report. In general, the confidence or uncertainty surrounding these estimates is not described. It can be seen that vector-borne diseases, particularly malaria, are consistently addressed. Other impacts that may have greater effects, such as weather disasters, are less well addressed.

It is important to distinguish between the process of conducting the assessment and the product. HIA is a policy tool therefore the process of conducting assessments, particularly the involvement of stakeholders, is very important. Yet information on the process aspects of these assessments is not widely available, and is not reviewed here. Stakeholder participation and evaluation are essential activities for a policy-orientated assessment process, discussed in chapter ten and elsewhere (37).

### **Developed countries**

The most important environmental health problem in developed countries is generally considered to be outdoor air pollution. For these countries, the focus of impacts of climate change was also the potential increase in heat stress and heatwaves. There was relatively little discussion of weather disasters except for the United Kingdom (33). The risk of vector-borne disease was considered important even if the diseases were not currently present in that particular country. The effect of climate and weather on food and water-borne diseases was also addressed, perhaps without sufficient attention.

The United States study involved a comprehensive review of the epidemiological literature for a number of climate sensitive diseases and exposures. An expert panel was formed, their conclusions summarised in Table 9.2. The assessment was well disseminated and summary documents for the health specific chapters were published as a special issue of a health journal (8, 35). The United States assessment health chapter team took the decision not to use modelling to quantify future estimates. It was decided that the primary objective was to produce a consensus document to serve as a foundation for future quantitative assessments. In contrast, the United Kingdom assessment was focussed totally on delivering quantitative results for the following outcomes (33) for three time periods and four climate scenarios:

- heat and cold related deaths and hospital admissions
- cases of food poisoning
- changes in distribution of *Plasmodium falciparum* malaria (global) and tick-borne encephalitis (Europe), and seasonal transmission of *P. vivax* malaria (UK)
- cases of skin cancer due to stratospheric ozone depletion.

The large uncertainty surrounding these estimates was acknowledged, the main source of uncertainty being the United Kingdom's capacity to control these diseases in the future. For example, cases of salmonella and levels of air pollutants are generally declining, therefore the climate-change attributable effects will decline also. The main conclusions of the report were the impact of increases in river and coastal flooding, and severe winter gales. This report also clearly addressed the balance between the potential benefits and adverse impacts of climate change: the potential decline in winter deaths due to milder winters is much larger than the potential increase in heat-related deaths. Climate change

**TABLE 9.2 Summary of the health sector assessment for the United States.** *Source: reproduced from reference (35).*

Potential health impacts	Weather factors of interest <sup>a</sup>	Direction of possible change in health impact	Priority research areas
Heat-related illnesses and deaths	extreme heat and stagnant air masses	↑	Improved prediction, warning and response Urban design and energy systems Exposure assessment
Winter deaths	extreme cold snow ice	↓	Weather relationship to influenza and other causes of winter mortality
Extreme weather events-related health effects storms	precipitation variability (heavy rainfall events) <sup>b</sup>	↑	Improved prediction, warning and response Improved surveillance Investigation of past impacts and effectiveness of warnings
Air pollution-related health effects	temperature stagnant air masses	↑	Relationships between weather and air pollution concentrations Combined effects of temperature/humidity on air pollution Effect of weather on vegetative emissions and allergens (e.g., pollen)
Water- and food-borne diseases	precipitation estuary water temperatures	↑	Improved monitoring effects of weather/environment on marine-related diseases Land use impacts on water quality (watershed protection) Enhanced monitoring/mapping of fate and transport of contaminants
Vector- and rodent-borne diseases	temperature precipitation variability relative humidity	↕	Rapid diagnostic tests Improved surveillance Climate-related disease transmission dynamic studies

<sup>a</sup> Based on projections provided by the National Assessment Synthesis Team. Other scenarios might yield different changes.

<sup>b</sup> Projected change in frequency of hurricanes and tornadoes is unknown.

also is anticipated to lead to a decline in air pollution-related illnesses and deaths, except for those associated with tropospheric ozone.

The Portuguese national assessment made several methodological advances (29). The following approach was used:

- assessment of current health status in Portugal
- identification of populations most vulnerable to climate change
- identification of mechanisms by which projected climate changes may affect health
- assessment of strategies that may reduce potential impacts on health
- identification of knowledge gaps.

The main findings of the Portuguese assessment were that climate change would lead to:

- an increase in heat-related deaths in Lisbon (cold related deaths were not addressed) even with full acclimatization;
- decline in meteorological conditions suitable for high nitrogen dioxide levels in Lisbon, but an increase in conditions suitable for high ozone levels;

- increased transmission of water and food-borne diseases due to higher temperatures (not quantified);
- increase in number of days per year suitable for malaria (*P. falciparum* and *P. vivax*), West Nile virus fever, and dengue transmission (based on temperature threshold model). However, the actual (rather than potential) risk of transmission was either low or none using a qualitative risk assessment method (Table 9.3);
- actual risk of increases in leishmaniasis and Mediterranean spotted fever were assessed to be medium to high;
- increased risk of leptospirosis transmission due to increased flooding.

**TABLE 9.3a Scenarios used in vector borne disease assessment.**

	Assuming current knowledge of vector and parasite prevalence in Portugal	Assuming the introduction of a small population of parasite infected vectors into Portugal.
Current climate	Scenario 1	Scenario 2
Climate change (2x CO <sub>2</sub> )	Scenario 3	Scenario 4

**TABLE 9.3b Potential risk of mosquito borne diseases in Portugal (Casimiro and Calheiros, 2002) (29).**

Disease	Scenario	Suitable Vector	Parasite	Risk Level
Vivax malaria	1	Widespread distribution	Imported cases only	Very low
	2	Focal distribution (new vector)	Low → high prevalence	Low
	3	Widespread distribution	Imported cases only	Very low
	4	Focal → potentially regional distribution (new vector)	High focal prevalence → high prevalence regional distribution	Low-Medium
Falciparum malaria	1	None present	Imported cases only	None
	2	Focal distribution	Low → high prevalence	Low
	3	None present	Imported cases only	None
	4	Focal v potentially regional distribution	High focal prevalence → high prevalence regional distribution	Low-medium
Dengue	1	None present	Imported cases only	None
	2	Focal distribution	Low → high prevalence	Low
	3	None present	Imported cases only	None
	4	Focal → potentially regional distribution	High focal prevalence → high prevalence regional distribution.	Low-medium
Yellow Fever	1	Widespread distribution	Imported cases only	Very low—None
	2	Focal distribution (new vector)	Low → high prevalence, focally distributed	Low
	3	Widespread distribution	Imported cases only	Very low
	4	Focal → potentially regional distribution (new vector)	Low prevalence, widespread distribution	Low medium
West Nile fever	1	Widespread distribution	Low prevalence, focally distributed	Low
	2	Focal distribution (new vector)	Low → high prevalence, focally distributed	Low
	3	Widespread distribution	Low → high prevalence, regionally distributed	Low medium
	4	Focal distribution (new vector)	Low → high prevalence, focally distributed	Low

Developed country assessments were more likely to identify research gaps and include an adaptation assessment. In all cases the adaptation assessment referred to planned measures or strategies (see Table 9.2).

### **Developing countries**

Assessments of adaptation (i.e. responses to the impacts of climate change) are linked to the development status of developing countries and those with economies in transition. Several initiatives have supported assessments in developing countries. The following programmes have provided financial and technical support, with a main focus on capacity building within the scientific and stakeholder communities:

- United States Country Studies Programme managed by USEPA (38)
- Country Studies Programme managed by UNEP, funded through Global Environment Facility (GEF) (15)
- Dutch Country Studies Programme
- Pacific Islands Climate Change Assistance Programme (PICCAP).

The Cameroon UNEP Country Study was restricted to looking at the impacts in only two regions: the coastal zone, the most densely populated area; and the Sudano-Sahelian zone, the poorest region in Cameroon (20). The burden of infectious diseases is high in this latter region (cholera, yellow fever, malaria). Water projects constructed for climate change response could increase malaria in dry regions, despite less rain being projected. Modelled projections for malaria and schistosomiasis were undertaken. Increased drought may lead to extension of the meningococcal meningitis season although there is little epidemiological literature to support this conclusion. Cholera is associated with flooding in the lowlands and therefore any increased flooding associated with climate change was anticipated to lead to an increase in cholera. Although Cameroon has an early warning system for cholera and meningitis epidemics, it was acknowledged as not fully operational due to lack of trained personnel. Major constraints in the health sector were identified as insufficient amounts of human, material and financial resources.

The United States country studies programme supported climate change studies in 49 developing countries and those with economies in transition, enabling these countries to develop emissions inventories, assess vulnerabilities to climate change, and evaluate response strategies for mitigation and adaptation. Zambia and Sri Lanka completed health assessments under this programme. Zambia qualitatively addressed the implications of climate change for infectious diseases such as malaria, schistosomiasis, cholera, dysentery, bubonic plague, and malnutrition (36). No modelling was undertaken and the assessment was limited by the lack of health data (38). Based on expert judgement, the study found that existing environmental health problems (due to environmental degradation) are likely to be exacerbated by climate change. Sri Lanka also studied the potential effects of climate change on malaria and concluded that this could become prevalent in areas that are currently clear. The effect of changes in population, income or quality of health care in these countries was not assessed.

The general conclusion from the developing country studies is that new innovative methods are needed, given the lack of data. It was also suggested that basic indicators of vulnerability be developed. The United States country studies pro-

gramme recognised that some of the methods proposed were not applicable to developing country situations.

### **Small island developing states**

Small Island Developing States (SIDS) have more incentive than most to undertake vulnerability and adaptation assessments. The effects of climate change in the Caribbean will be felt through increasingly severe tropical storms and likely increases in the severity and frequency of low rainfall events and droughts in all areas (39). The UNEP country study report for Antigua and Barbuda found droughts and hurricanes to be of particular concern. The methods described in the UNEP handbook were followed. However, only one vector-borne disease was considered (dengue) because this disease is currently present on the islands. A dengue model (40) was used to assess changes in the seasonal pattern of epidemic potential (EP). An assessment of the local relationship between dengue and climate, using local records on the Infestation Index (an index of dengue risk), was inconclusive. Antigua's assessment was very useful as it provided a comprehensive assessment of the current health system and its adaptive capacity in relation to specific diseases, such as the cholera and food safety plans.

The Fijian assessment's health chapter (22) addresses current health status in the context of health services and other provision. Fiji's main concerns were dengue fever (recent epidemic in 1998), diarrhoeal disease and nutrition related illness. The islands are malaria free and a mosquito vector (*Anopheles*) population has not been established despite a suitable climate. The risk of introduction and establishment of malaria and other mosquito borne diseases due to climate change was considered to be very low therefore. Filariasis, an important vector-borne disease on the islands, is likely to be affected by climate change due to higher temperatures. The distribution of the vector (*Aedes polynesiensis*) may be affected by sea level rise as it breeds in brackish water.

Climate change was anticipated to increase the rates of diarrhoeal disease in Fiji and Kiribati due to decreases in rainfall and increases in temperature. Evidence was not presented to show current association between flooding or heavy rainfall and cases of diarrhoea. However, the 1997/98 drought (associated with El Niño) had widespread impact, including malnutrition and micronutrient deficiency in children and infants (41).

The Kiribati assessment quantified potential impacts of climate change on cases of ciguatera fish poisoning, dengue fever and diarrhoeal diseases (25). Kiribati has the highest rates of ciguatera in the Pacific. A linear relationship between sea surface temperature anomalies and annual cases of ciguatera (42) was extrapolated to estimate future reported cases and incidence using air surface temperature as a parameter of future changes in sea surface temperature. The study suggests an increase in cases of ciguatera under climate change. The many caveats of this approach were clearly stated, including the extrapolation of a relationship beyond the temperature range observed in the original study. Further, this model does not take account of other factors, such as human behaviour or the effect of climate warming on the reef ecosystems.

For both Kiribati and Fiji, a dengue transmission model was incorporated into PACCLIM, a climate impacts model developed for the Pacific Islands (DenSIM) (40). The model estimates changes in EP (epidemic potential), a relative indicator of potential transmission based on temperature (assuming other factors remain constant) for selected population centres: Nadi, Suva (Fiji), South Tarawa

(Kiribati). Dengue is primarily an urban disease (see chapter 6 on vector-borne disease). The outcome measures EP was related to categories of risk of epidemics, however it had not been validated for these populations. The modelling indicates that climate change may extend the transmission season and geographical distribution in Fiji (not examined in Kiribati). In the Kiribati assessment, absolute values and changes in EP are reported for decadal means that are difficult to interpret.

## Recommendations for developing methods and tools

Assessments of the potential health impacts of climate change have used a variety of methods and tools. Both qualitative and quantitative approaches may be appropriate depending on the level and type of knowledge. The outcome of an assessment need not be quantitative for it to be useful to stakeholders. An integrated approach is likely to be an informative approach as climate impacts are likely to transcend traditional sector and regional boundaries. Impacts in one sector may affect the capacity to respond of another sector or region.

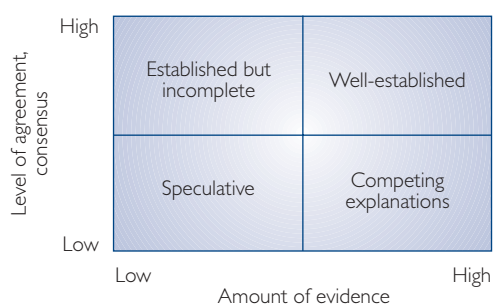
It is important to distinguish between epidemiological methods and health impact assessment methods. Current epidemiological research methods are best able to deal with the health impacts of short-term (daily, weekly, monthly) variability, which require only a few years of continuous health data (43). In contrast, health impact assessment methods address the application of epidemiological functions to a population to estimate the burden of disease. Attributable burdens can only be estimated for those weather-disease relationships for which epidemiological studies have been conducted. The available evidence indicates that weather-disease relationships are highly context specific and vary between populations, therefore such models need to be derived from data from relevant populations.

The IPCC has developed formal methods of reporting uncertainty in assessments (44). Figure 9.2 illustrates the importance of communicating to policy-makers the scientific evidence behind particular estimates. Further, the IPCC authors were encouraged to apply probabilities to statements regarding future impacts. To ensure that these probabilities were reported consistently a quantitative scale was agreed, for example, “high” confidence referred to probabilities of 67–95%, and “very high” confidence referred to probabilities greater than 95%.

These methods are suitable for health impact assessment and were applied in the Portuguese assessment (29). The standard epidemiological approach to quantifying uncertainty relates to the use of confidence intervals around estimates. It is not possible to apply these to the results of scenario-based health risk assessment when biological or processed based models are used. However, new approaches to quantifying uncertainty that apply Bayesian methods have been developed. It is important to specify the likely range of uncertainties and the magnitude and direction of errors.

## Literature reviews

Only the well-funded assessments (e.g. Canada, United States) have been able to include comprehensive literature reviews. Reviewing the literature and consulting experts are both processes open to bias and inaccuracies (45). Robust and transparent methods are needed. There is a problem with a lack of published



**FIGURE 9.2 Uncertainty assessment.**

Source: reproduced from reference 44.

studies on climate/weather and health outcomes, and the limited scope for extrapolation given that such relationships are highly context-specific. An additional problem has been that some relevant literature comes from non-health disciplines (e.g. air quality studies) and therefore difficult to detect and easy to overlook. This underscores the need for a multi-disciplinary writing team. No assessment so far has published search protocols or specified criteria for inclusion/exclusion, or made formal attempts to assess the quality of individual studies.

Considerable time, effort and resources are required to undertake a systematic and comprehensive literature review, usually beyond the means available. Many assessments rely too heavily on the IPCC Assessment Reports that necessarily lack geographical specificity. There is considerable opportunity for the assessments to address more relevant problems of the population in question. In most cases such opportunities have been lost.

The literature review should focus on the following evidence:

- mechanisms by which climate change may affect health;
- estimates of current burden of climate-sensitive diseases;
- estimates of future burden of climate-sensitive diseases using scenario based modelling;
- descriptions of future vulnerability to climate change, particularly identification of most vulnerable groups/populations/locations;
- studies that address early health effects of climate change;
- how to identify and evaluate impacts of climate variability on health.

### **Predictive modelling**

Quantified scenario-driven modelling was undertaken in several assessments using a range of methods (see chapter 6 on vector-borne disease). It is likely that climate change will affect vector-borne disease. The majority of predictive modelling studies have estimated future changes in the distribution of vectors and/or measures of disease risk within existing, or predicting newly endemic, areas (see review in chapter 7).

The model used in Fiji and Kiribati to estimate changes in dengue transmission was not derived for that area, but was a biological model that relied on generalised assumptions about dengue transmission. This had limited value for a local study, its application is therefore unknown, and ideally requires validation with local data. Most model outcomes were assessed for long time periods (2020s, 2050s and 2080s) rather than periods of more relevance to public health. This was primarily because the climate scenarios were available only for those time periods and did not address the needs of the health sector.

## **Use of climate scenarios**

National climate scenarios were available for several of the assessments (United Kingdom, United States, Portugal, Fiji, Kiribati). As noted above, there is great uncertainty on future changes in climate at local or national level. In order to address such uncertainty around future climate projections, impacts studies should consider a range of emission scenarios and a range of climate models. In practice this is not always feasible, climate scenarios are expensive to produce and impact groups must use what is available. The United Kingdom study was able to address four climate scenarios based on assumptions of future emissions (high, medium-high, medium-low and low estimates), and the Portuguese study compared the output from two different regional climate models (PROMES and HadRM2).

Climate information was not available for all assessments. Antigua and Barbuda found that the recommended climate scenarios did not even resolve the islands from the ocean. Analogue scenarios were used in this assessment (46) (see chapter 2 on climate). The Pacific Islands used PACCLIM, a climate change integrated assessment model for the Pacific region. In addition to analogue scenarios, simple climate models (e.g. COSMIC and MAGIC) can be used to give a range of climate scenarios based on a range of climate models and sensitivities, and emissions scenarios. COSMIC (Country Specific Model for Intertemporal Climate) contains simplified versions of the 14 different climate models used by the IPCC, and gives output at the country level (47).

When discussing (or quantifying) the range of future impacts it is important to use a range of scenarios in order to address the uncertainty surrounding future emissions that drive climate change, and inherent within the climate models. However, when planning adaptation measures, it may be most appropriate to address the upper limits of the projections. A report on impacts in small islands recommended planning for the worst-case scenario—i.e. the top range of the climate scenarios—5 or 6°C temperature rise by 2100, and sea level rise of 0.9 m (39).

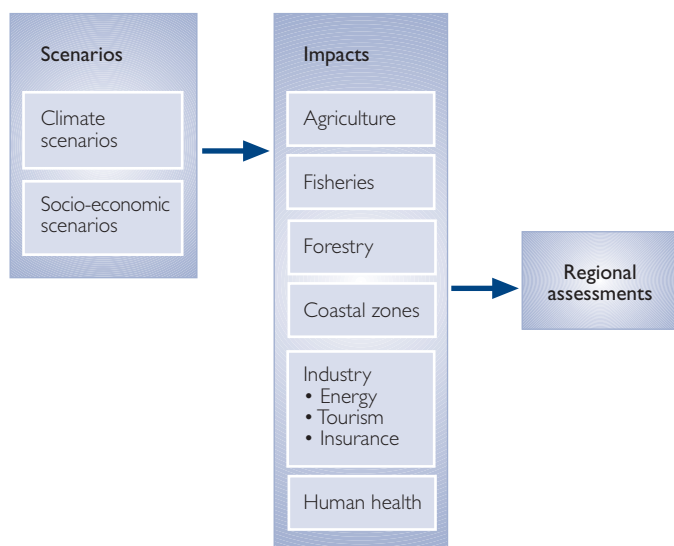
## **Integrated assessment**

In order to optimise their use to decision-makers, assessments should integrate across all relevant sectors. This also involves stakeholder needs assessment (discussed in chapter 12) due to the multi-objective nature (or tradeoffs) inherent within any policy responses to climate change health risks. Within an integrated assessment framework, physical, biological and societal system responses and assumptions can be simulated. This, in turn, affords improved guidance in decision evaluation when comparing policy tradeoffs in terms of potential risks or benefits.

## **Integration between sectors**

All major economic sectors are likely to be affected by climate change. These impacts should be included in the assessments because of the:

- direct impacts of climate change and health implications, e.g. loss of food supply
- impacts of responses to climate change (adaptation and mitigation strategies). This assessment is within the traditional role of health impact assessment i.e. that specific projects should be evaluated.



**FIGURE 9.3 Multi-sectoral assessments: example of typical sectors addressed within a national assessment.** Each box represents an expert group and chapter within final report.

Figure 9.3. describes the sectors typically included in climate change impact and vulnerability assessments. There was a consistent lack of integration between the sectors in the multi-sectoral assessments. By integration, we mean that the water assessment provides information for the health assessment and vice versa. This has been identified consistently as a problem for climate change assessments. Health risk assessment emphasises the need for monitoring of human diseases in relation to climate and environmental factors.

The United Kingdom Climate Impacts Programme (UKCIP) supports climate impact assessments in the United Kingdom although no specific guidelines have yet been developed. UKCIP promotes the need for a cross-sectoral and integrated approach to impact assessments as they are unlikely to respect sectoral or regional boundaries. In particular, impacts on health will depend on the impacts of climate change on water resources management, transport, and coastal and flood plain infrastructure, as well as the responses to those impacts. The Portuguese assessment was able to make use of the results from other sectoral assessments, particularly for future flood risk and water availability.

There was some consideration of cross-sectoral impacts in the developing country studies. In Antigua and Barbuda, it was recommended that the government consider an incentive scheme to encourage the public to construct larger water storage tanks to collect rainwater. However, the health sector made a recommendation to reduce the storage of water because such tanks are a known breeding site for the dengue vector.

### **Integration across a region**

Countries in close proximity will generally experience similar climatic conditions and—if socioeconomically alike—similar vulnerabilities to climate change. The regional scale approach can offer a useful organisational unit on which to co-ordinate and evaluate research cognisant of socioeconomic needs and geographical and jurisdictional boundaries. In this setting assessment of critical climate-sensitive issues can augment nation-specific assessments, affording a more complete assessment of risk and vulnerabilities in a region commensurate

with the design and support of effective adaptation responses (discussed below). Region-based (multi-national) assessment frameworks are encouraged where common climate exposures and health outcomes occur (e.g. Pacific Island or Southern African nations).

## Adaptation assessment

In most assessments adaptation typically is addressed by recommendations for measures or interventions (Table 9.4). That is, what should be done now to reduce the potential health impacts of climate change. The autonomous responses to climate change that will tend to reduce impacts are often poorly described: the non-climate factors that affect health are not fully considered. The relative contributions of climate and non-climate factors should be discussed in the context of current sensitivity and future vulnerability.

Climate adaptation and sustainability goals can be advanced jointly by changes in policy that lessen pressure on resources, improve management and environmental risks, and enhance adaptive capacity. An analysis of the IPCC guidelines for coastal zone management found greater emphasis on assessing impacts rather than adaptation and that impact studies include poor assessment of autonomous adjustments (adaptations “likely” to occur without additional policy incentives) (48). For health impact assessment, autonomous adjustments would include the physiological and behavioural acclimatization of populations.

The literature distinguishes between specific adaptations (discussion of specific measures or health interventions) and general adaptive capacity. Adaptive capacity has been defined as the enabling environment and relates to institutional and environmental issues, often clearly linked to sustainable development. Strengthening and maintenance of the public health infrastructure will increase adaptive capacity.

Specific adaptation assessment may be addressed in four increasingly complex ways:

1. List of adaptation options/strategies/policies with no evaluation
2. Estimation of the health benefit or effectiveness of specific strategies
3. Evaluation of specific strategies e.g. cost-effectiveness analysis
4. Policy analysis that addresses the feasibility of implementation of specific strategies or policies

Only step 1 has been seen in the assessments reviewed so far. The UNEP country studies placed heavy emphasis on the analysis of adaptation strategies for climate change—with a focus on dealing with current vulnerability to climate variability and extremes—the win-win strategies (15). For example, Samoa advises a no-regrets approach, defined as strategies that benefit both society and the environment in the long-term in spite of initial economic costs. A range of sectoral adaptation measures were qualitatively assessed, based on economic and environmental costs, cultural suitability and practicability (49). The UNEP Country Studies Assessment concluded that technology transfer was not required but that there needed to be an increase in institutional capacity to regulate environmental issues—e.g. settlement patterns or over-use of resources (15).

## Review of National Communications to the United Nations Framework Convention on Climate Change

The UNFCCC is the international legal mechanism under which national governments are responsible for reducing greenhouse gas emissions, with the aim of avoiding, postponing or reducing the environmental, economic, and social impacts of climate change. Assessments of vulnerability and adaptation address a country's response to climate change. Article 4(f) of the UNFCCC states:

*“All Parties [. . .] shall: Take climate change considerations into account, to the extent feasible, in their relevant social, economic and environmental policies and actions, and employ appropriate methods, for example impact assessments, formulated and determined nationally, with a view to minimising adverse effects on the economy, on public health and on the quality of the environment, of projects or measures undertaken by them to mitigate or adapt to climate change.”*

Whether and how an impact assessment is conducted is based on a country's voluntary decision. Although several agencies have produced guidelines on how to assess the impacts of climate change, no standard approach has been developed with regard to human health and a comparative mechanism is not in place.

These reports (referred to as National Communications) are submitted to the UNFCCC which provides guidelines to promote consistent reporting. There are few references to human health within these guidelines. Countries decide what additional information they want to submit to the secretariat. Most Annex I parties (most developed countries) submitted their first report in 1994 or 1995 and their second in 1997. Most parties with economies that were in transition submitted their second communications in 1998 (according to the longer time-frame granted to them). The third national communication for Annex I parties was due in November 2001.

All national communications available online from the UNFCCC website, and in English, in March 2002 were reviewed to see if they addressed health. Most Annex I countries do not address health impacts. Some countries address health but conclude that climate change impacts on health are of “no great concern” (e.g. Austria, Denmark). Where health is mentioned, a range of impacts is discussed, primarily based on the IPCC conclusions. Italy and Japan address health in some detail. The potential impacts on health were not well addressed in the assessments of non-Annex I countries, except for the small island states that have conducted extensive vulnerability assessments. These populations are considered extremely vulnerable to climate change and also contribute significantly to the UNFCCC process. Table 9.4 summarises the conclusions of National Communications in non-Annex I countries (i.e. developing countries) on strategies to reduce the impacts on human health. The range of impacts is similar as countries identify familiar concerns of increases in vector-borne disease, food and water-borne disease, heat stress, air pollution and impacts from natural disasters (such as floods and droughts).

The National Communications are important and address a range of issues that support the Framework Convention, primarily for national inventories of greenhouse emissions. The potential impacts of climate change in economic sectors (e.g. agriculture) are typically well-addressed (50). National Communications provide invaluable information about vulnerability to the impacts of climate change. Many governments recognise that there are important gaps in knowledge of the relationship between human health, social change and

**TABLE 9.4 Non-Annex I countries: summary of conclusions of National Communications for adaptation to reduce health impacts of climate change, as supplied to the United Nations Framework Convention on Climate Change.**

Country	Date of submission	Adaptation strategies
Bolivia	16/11/00	<ul style="list-style-type: none"> <li>• Environmental Care</li> <li>• Sanitary Education</li> <li>• Reservoir Control</li> <li>• Decreasing vector/human contact</li> <li>• Epidemic/climate warning</li> <li>• Biological control</li> <li>• Chemical Control</li> </ul>
Colombia	18/12/01	Strengthen prevention and control of malaria and dengue
Cook Islands	30/10/99 revised edition March 2000	<p>Specific capacity building needs</p> <ul style="list-style-type: none"> <li>• Regular access to workshops, conferences, meetings and internet services</li> <li>• Education and awareness</li> <li>• Training and equipment</li> <li>• Integrated pest management systems</li> <li>• Legislation</li> </ul>
Indonesia	27/10/99	<ul style="list-style-type: none"> <li>• promote use of environmentally friendly fuels and healthy transportation system</li> <li>• promotion of healthy environment housing</li> <li>• promotion of emergency response system for sporadic climate change disaster</li> </ul>
Malaysia	22/08/00	Strengthening existing emergency preparedness and disaster management programme for international health surveillance and monitoring systems. Multidisciplinary approach and collaboration with other agencies—such as, agricultural, meteorological, environmental and planning agencies—will be intensified to ensure adequate weight given to health impacts due to climate change in Malaysia
Marshall Islands	24/11/00	Develop comprehensive suite of human health policies to address water borne diseases and other sicknesses related to climate-induced change, including those arising from poor water quality and nutrition
Niue	02/10/01	<ul style="list-style-type: none"> <li>• Health education and promotion programmes to incorporate health impacts of climate change on infectious diseases</li> <li>• Future health services delivered on Niue to acknowledge emerging infectious diseases with an adaptive perspective on human health impacts</li> <li>• Preventative health programmes and projects within Public Health division to be strengthened and supported, with emphasis on community involvement in the projects</li> <li>• Policies for disaster preparedness with adaptive strategies to be formulated and implemented</li> <li>• Database and information system to be established for accurate monitoring and data collation</li> </ul>
Papua New Guinea	27/02/02	Adaptation measures
Saint Kitts & Nevis	30/11/01	<ul style="list-style-type: none"> <li>• Development of Health Forecast System for acute respiratory, cardiovascular and many other diseases</li> <li>• Strengthening of data collection and reporting systems</li> <li>• Vaccination campaigns for all possible diseases</li> <li>• Sustained and improved sanitary conditions in human settlements</li> <li>• Sustained and improved disease vector control</li> <li>• Educational and promotional health related public campaigns</li> </ul>

**TABLE 9.4 Continued**

Country	Date of submission	Adaptation strategies
Saint Lucia	30/11/01	<ul style="list-style-type: none"> <li>• Public awareness</li> <li>• Surveillance and monitoring</li> <li>• Infrastructure development</li> <li>• Engineering and technological responses</li> <li>• Medical interventions</li> </ul>
Samoa	30/10/99	<ul style="list-style-type: none"> <li>• Health education and awareness need to be implemented at a community level. Regular cleaning campaigns need to be conducted for sites and places where mosquito vector is abundant</li> <li>• Conduct research programmes on the use of biological control.</li> <li>• Encourage development of proper waste disposal methods to minimise existence of vector breeding habitats.</li> <li>• Reliable and safe drinking water supply is essential.</li> </ul>
Seychelles	15/11/00	In view of considerable lack of data and expertise on the nature and magnitude of these impacts, it is important to undertake research both at population and individual levels so as to provide a solid basis for the formulation of adaptation strategies.
Sri Lanka	06/11/00	<p>Increase awareness of climate change in health sector Detailed responses with respect to following impacts</p> <ul style="list-style-type: none"> <li>• Natural disaster preparedness</li> <li>• Heat stress, heat-related illnesses and disorders</li> <li>• Spread of infectious diseases</li> <li>• Food shortage and nutritional disorders</li> </ul>
Thailand	13/11/00	Chemical control of outbreak of malaria may not be appropriate due to disease resistance and ecological effects. More research and development of alternative approaches to control possible malaria outbreaks are required.
Vanuatu	30/10/99	<ul style="list-style-type: none"> <li>• Promotion of hygienic waste disposal methods will help to prevent contamination with disease pathogens in the event of cyclones and floods.</li> <li>• Management of surface water catchments will help to maintain quality of domestic water and continuity of water supply.</li> </ul>
Zimbabwe	25/05/98	Health impacts, i.e. from malaria, will require investments in education and prevention techniques such as netting, repellents, and low-cost anti-malarial drugs.

environmental problems arising from climate-induced change. To date only limited attention has been given to understanding specific ways in which changes in population size and settlement density, economy and traditional practices are creating heightened vulnerability to health problems arising from climatic variations. There is a need to determine development policies to lessen the health impacts arising from vulnerability to climate change.

## Conclusions

Health impacts have not been well addressed in the climate change impact assessments, which have followed the climate assessment methods rather than health specific approaches. Assessments should be driven by region and country priorities in order to determine which health impacts are considered. No single set of guidelines can cover all health and institutional situations.

The most effective HIA is a prospective activity. A further distinction can be made between interventions where health changes are an explicit objective (e.g. vaccination programmes) and where they are not explicitly part of the objectives (e.g. energy policy). As with other areas of environmental health impact assessment, there is a need to create awareness of the problem. There is also concern that health impact assessments are not incorporated into the UNFCCC National Communications and other climate change assessments, strategies or action plans.

Assessments should set an agenda for future research. Nearly all the assessments identify research gaps and often specify narrow research questions that should be answered. Assessment also should be linked to follow up activities such as monitoring and revised reports. A major shortcoming of many climate change impact assessments has been the superficial treatment of the adaptive capacities and options of diverse populations (6). Strategies to enhance population adaptation should promote measures that are not only appropriate for current conditions but also build the capacity to identify and respond to unexpected future developments. The restoration and improvement of general public health infrastructure will reduce vulnerability to the health impacts of climate change. In the longer-term and more fundamentally, improvements in the social and material conditions of life and the reduction of inequalities within and between populations are required for sustained reduction in vulnerability to global environmental change.

The development of guidelines would improve methods used in assessments, allow for some standardization and the development of a set of indicators (51). Health Canada has prepared an initial framework (52). There are three distinct phases:

1. Scoping: to identify the climate change problem (concerns of vulnerable groups) and its context, describe the current situation (health burdens and risks) and identify key partners and issues for the assessment.
2. Assessment: estimations of future impacts and adaptive capacity, and evaluation of adaptation plans, policies and programmes.
3. Risk management: to minimize the impacts on health and follow-up assessment process and health risk management actions.

Health impacts assessment requires guidelines that fit in with the larger HIA framework of WHO and other international agencies. There is a need to move beyond the climate change environmental policy domain and into the public health arena. Guidance is needed on capacity and needs assessment. In most countries the policy environment does not encourage intersectoral collaboration. Policies for resource allocation in the health sector aim at dealing with problems of the present with the highest burden of disease. Unfortunately, the medical perspective (i.e. provision of health services in clinics/hospitals) prevails over the public health perspective (i.e. activities to prevent disease) in much policy-making.

## References

1. World Health Organization (WHO). *Health impact assessment as a tool for intersectoral health policy*. WHO European Centre for Environment and Health/European Centre for Health Policy, 1999.

2. BMA. Health and environmental health impact assessment. London, UK, Earth-Scan, 1999.
3. McMichael, A.J. et al. Human population health. In: *Climate change 1995: impacts, adaptations, and mitigation of climate change: scientific-technical analyses*. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK, Cambridge University Press: 561–584, 1996.
4. McMichael, A.J. & Githeko, A. Human health. In: *Climate change 2001: impacts, adaptation, and vulnerability*. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. McCarthy, J.J. et al. eds. New York, USA, Cambridge University Press, pp. 451–485, 2001.
5. Carter, T.R. et al. *IPCC Technical guidelines for assessing climate change impacts and adaptations*. London, UK, University College, 1994.
6. Parry, M.L. & Carter, T. *Climate impact and adaptation assessment*. London, UK, Earth-Scan, 1998.
7. Lock, K. Health impact assessment. *British Medical Journal* 320: 1395–1398 (2000).
8. Bernard, S. & Ebi, K.L. Comments on the process and product of the health impacts assessment component of the national assessment of the potential consequences of climate variability and change for the United States. *Environmental Health Perspectives* 109: supplement 2: 1877–1884 (2001).
9. Kunzli, N. et al. Public health impact of outdoor and traffic related air pollution: a European assessment: *Lancet*, 356: 795–801 (2000).
10. Berry, J.E. *Power generation and the environment: the UK perspective*. Vol. 1. Abingdon, UK: AEA Technology, 1998.
11. IPCC-TG CIA. *Guidelines on the use of scenario data for climate impact and adaptation assessment. Version 1*. Prepared by Carter, T. et al. Intergovernmental Panel on Climate Change, Task Group on Scenarios for Climate Impact Assessment, pp. 69, 1999. [http://ipcc-ddc.cru.uea.ac.uk/cru\\_data/](http://ipcc-ddc.cru.uea.ac.uk/cru_data/).
12. Smit, B. et al. An anatomy of adaptation to climate change and variability. *Climatic Change* 45: 223–251 (2000).
13. Nakicenovic, N. & Swart, R. *Emissions Scenarios*. A Special Report of Working Group III of the Intergovernmental Panel on Climate Change. New York, USA, Cambridge University Press, 2001.
14. Balbus, J.M. et al. Human health. In: *Handbook on methods of climate change impact assessment and adaptation strategies*, version 2.0. Feenstra, J.F. et al. eds. Nairobi: UNEP/ Amsterdam, Institute for Environmental Studies, 1998.
15. O'Brien, K. Developing strategies for climate change: The UNEP Country Studies on Climate Change Impact and Adaptation Assessment. *CICERO Report 2000:2*. Oslo, Norway, University of Oslo, 2000. <http://www.cicero.uio.no/media/314.pdf>.
16. Carter, T.R. & La Rovere, E. Developing and applying scenarios. In: *Climate change 2001: impacts, adaptation, and vulnerability*. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Eds. McCarthy, J.J. et al. New York, USA, Cambridge University Press, pp. 145–190, 2001.
17. O'Marde, D. & Michael, L. Human Health. In: *Antigua and Barbuda climate change impacts and adaptation assessments*. UNEP Country Studies Programme, 2000.
18. NHMRC. *Health implications of long term climatic change*. Canberra, Australia, Australian Government Publishing Service, 1991.
19. McMichael, A.J. et al. *Risk assessment regarding human health and climate change in Australasia*. Draft report submitted to Australian Government (2002).
20. UNEP/Ministry of Environment and Forestry, Cameroon. *Country case study on climate change impacts and adaptation assessment. Volume 2*. Cameroon: UNEP, Nairobi, and Ministry of Environment and Forestry, Cameroon, 1998.
21. Duncan, K. et al. Health Sector, Canada Country Study: *Impacts and adaptation: Environment Canada*, pp. 520–580, 1997.

22. de Wet, N. & Hales, S. Human health. In: *Climate change vulnerability and adaptation assessment for Fiji*. Prepared for World Bank Group by International Global Change Institute, in partnership with South Pacific Regional Environment Programme (SPREP) and PICCAP, 2000.
23. Ando, M. Health. In: *The potential effects of climate change in Japan*. Nishioka, S. et al. eds. Tsukuba, Japan, Center for Global Environmental Research/National Institute for Environmental Studies, pp. 87–93, 1993.
24. Ando, M. et al. Health. In: *Global warming: the potential impact in Japan*. Nishioka, S. & Harasawa, eds. Tokyo, Japan, Springer Verlag, pp. 203–214, 1998.
25. Taeuea, T. et al. Human health. In: *Climate change vulnerability and adaptation assessment for Kiribati*. Prepared for World Bank Group by International Global Change Institute, in partnership with South Pacific Regional Environment Programme (SPREP) and PICCAP, 2000.
26. Martens, W.J.M. ed. *Vulnerability of human population health to climate change: state-of-knowledge and future research directions*. Bilthoven, Netherlands, Dutch National Research Programme on Global Air Pollution and Climate Change, Report No. 410200004, 1996.
27. Woodward, A. et al. *Climate change: potential effects on human health in New Zealand*. A report prepared for the Ministry for the Environment as part of the New Zealand Climate Change Programme. Wellington, New Zealand, Ministry for the Environment, 2001.
28. Sempris, E. & Lopez, R. eds. *Vulnerability and adaptation to the adverse impacts of climate change in the health sector*. National Program on Climate Change, National Environment Authority ANAM/UNDP (2001).
29. Casimiro, E. & Calheiros, J.M. Human Health. In: *Climate Change in Portugal: scenarios, impacts and adaptation measures—SIAM project*. Santos, F.D. et al. eds. Lisbon, Portugal, Gradiva, 2002.
30. Ratnasari, J. ed. *Final report of the Sri Lanka climate change country study: March 1998*. Colombo, Sri Lanka, Ministry of Forestry and Environment—Environment Division, 1998.
31. St Lucia climate change and vulnerability assessment. St Lucia's initial national communication to the UNFCCC, Chapter 4, 2002.  
<http://unfccc.int/resource/docs/natc/lucnc1.pdf>.
32. Climate Change Impacts Review Group (CCIRG). *Review of the potential effects of climate change in the United Kingdom*. London, UK: HMSO, 1996.
33. Department of Health. *The Health Effects of Climate Change in the UK*. London, UK: HMSO, 2002.
34. USEPA. *The potential effects of global climate change on the United States* Washington DC, USA: USEPA, Office of Policy, Planning and Evaluation, EPA 230-05-89-057, 1989.
35. Patz, J.A. et al. The potential health impacts of climate variability and change for the United States: executive summary of the report of the health sector of the US National Assessment. *Environmental Health Perspectives* 108: 367–376 (2000).
36. Phiri, J.S. & Msiska, D.B. *Vulnerability and adaptation studies: health impact assessments*. Environment Council of Zambia, 1998.
37. Scheraga, J.D. & Furlow, J. From assessment to policy: lessons learned from the US national assessment. *Human and Ecological Risk Assessment* 7: 1227–1246 (2001).
38. Smith, J.B. & Lazo, J.K. *A summary of climate change impacts assessments from the US Country Studies program*. Unpublished document. Boulder: Stratus Consulting (2001).
39. Sear, C. et al. *The impacts of global climate change on the UK overseas territories: technical report and stakeholder survey*. Natural Resources Institute/Tyndall Centre of Climate Change Research, UK, 2001.
40. Focks, D.A. et al. A simulation model of epidemiology of urban dengue fever: literature analysis, model development, preliminary validation, and samples of

- simulation results. *American Journal of Tropical Medicine and Hygiene* 53(5): 489–506 (1995).
41. OCHA. *UNDAC Mission Report Fiji Drought*. UN Office for Co-ordination of Humanitarian Affairs, 1998.
  42. Hales, S. et al. Ciguatera fish poisoning, El Niño and Pacific sea surface temperatures. *Ecosystem Health* 5: 20–25 (1999).
  43. Kovats, R.S. & Bouma, M.J. Retrospective studies: analogue approaches to describing climate variability and health. In: *Environmental change, climate and health: issues and research methods*. Martens, P & McMichael, A.J. eds. Cambridge, UK, Cambridge University Press, 2002.
  44. Schneider, S. & Moss, R. Uncertainties in the IPCC TAR. Recommendations to lead authors for more consistent assessment and reporting. Unpublished document (1999).
  45. Parry, J. & Stevens, A. Prospective health impact assessment: pitfalls, problems and possible ways forward. *British Medical Journal* 323: 1177–1182 (2001).
  46. Ebi, K.L. & Patz, J.A. Epidemiologic and impact assessment methods. In: *Health impacts of global environmental change: concepts and methods*. Martens, P. & McMichael, A.J. eds. Cambridge University Press, 2002.
  47. Schlesinger, M.E. & Williams, L.J. COSMIC (Country Specific Model for Intertemporal Climate) 1997.
  48. Klein, R.J.T. *Adaptation to climate change in German official development assistance: an inventory of activities and opportunities with a special focus on Africa*. Eschborn: Deutsche Gesellschaft für Technische Zusammenarbeit, 2001.
  49. World Health Organization (WHO). *Climate variability and change and their health effects in Pacific Island countries*. Report of a Workshop in Apia, Samoa, 25–28 July 2000. Geneva, Switzerland, WHO, 2001 (WHO/SDE/OEH/01.1).
  50. Intergovernmental Panel on Climate Change (IPCC). *Climate Change 1995: Impacts, adaptations, and mitigation of climate change: scientific-technical analyses*. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK, Cambridge University Press, 1996.
  51. World Health Organization (WHO). *Environmental Health Indicators: Framework and methodologies*. Geneva, Switzerland: WHO, 1999. [WHO/SDE/OEH/99.10].
  52. Health Canada (2002) National Health Impact and Adaptation Assessment Framework and Tools. Climate Change and Health Office, Health Canada, Ottawa.