Climate Change and Rural Child Health

Erica Bell
Bastian M. Seidel
Joav Merrick
Editors

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CLIMATE CHANGE AND RURAL CHILD HEALTH

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FOREWORD

There can be no surer indicator of a society's wellbeing than the health of its children. As a child-focused development agency, World Vision works with poor rural communities in every region of the world. Over the past 60 years, the world has seen gradual and hard-won progress in reducing child mortality and improving the lives of opportunities of children. Some of this is attributable to medical science, much of it to simple but effective public health measures. Even though 24,000 children continue to die each day from preventable causes, this represents a dramatic improvement, and progress continues to be made.

In 2000 the world's leaders agreed to the Millennium Development Goals - a real plan, with measurable targets, to combat poverty and address the world's most critical development concerns. While the goals are far from perfect, they have succeeded in creating focus and accountability in driving policy and resources towards real improvements in health, education and living standards. Critically, goals 4 and 5 recognise the importance of child health, which is inextricably linked to the health and wellbeing of mothers.

Climate change threatens to undo all of this progress, and wipe out the gains of decades. We are already seeing evidence that disastrous weather events are becoming more frequent and more intense. The catastrophic flooding that hit Pakistan in 2010, for example, has displaced millions of people. Just the year before, neighbouring India experienced the worst drought in 40 years, causing immense suffering to farming communities across the country. The threat of rising sea levels, the potential loss of productive farmland and the potential threat to water supplies are all profound concerns, and threaten the wellbeing of children and communities around the world.

In these circumstances citizens and especially leaders need to be reminded of the connection between climate action and the future of children's health. We need the best knowledge base, the best thinking, and real commitment to mitigation and adaptation measures. In this endeavour scientists, social scientists, political and community leaders, educators, health workers and ordinary citizens all need to play their part. This collection brings together some important contributions from a wide range of individuals working across these fields. The editors and all the contributors are to be commended and I urge and pray that this book will be widely read and its lessons applied.

Reverend Tim Costello, AO
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INTRODUCTION

CLIMATE CHANGE AND RURAL CHILD HEALTH

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Climate change is one of the biggest threats to human health in the 21st Century. Many climate change 'hotspots' lie in rural and remote communities. Within these communities rural children represent a most vulnerable group that has been relatively neglected in the climate change research. Researchers and health professionals have gathered material together in this book to focus international attention on the impacts of climate change on rural child health and appropriate responses. This book includes contributions from some of the world's leading climate change researchers, who were asked to explore the implications of their research for rural child health. The chapters offer conceptual understandings, implications for health and allied health practice, and analyses of appropriate policy responses. This book examines special issues in climate change and rural child health, providing disease-based analyses as well as consideration of education and development assistance issues. It also offers an examination of country-level issues suggesting the great diversity of impacts and the importance of considering regional effects.

Collectively, the contributions from these diverse authors show that understanding the effects of climate change on rural child health is about developing new ways of understanding interactions between individual health, community, and environment. The chapters suggest how local cultural and social factors, as well as big global events such as the global financial

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crisis, will continue to shape rural child health. This book explores a new frontier of health research to provide a diverse examination of the needs of this most climate-vulnerable group.

Our book is designed to be used as a point of departure for developing climate change research, policy and adaptation responses. It focuses on what the evidence across the disciplines, not just in climate change, suggests for research, policy and adaptation practice. Collectively, these chapters explore a wide range of issues such as

- sustainability education for children
- child rights and equity
- specific impacts of climate change on child health as they relate to, for example, helminthic diseases, aeroallegens and diarrhoeal disease
- the too-often neglected needs of particular groups such as indigenous children.

The chapters have been commissioned by the editors from authors with expertise either in climate change or rural child health (but rarely in both). Thus this book focuses on what can be learned by working across the boundaries, providing theoretical insights, summaries of relevant bodies of knowledge and policy, suggestions for further reading and other practical information designed to help focus attention on the health needs of rural children. While the emphasis is on exploring new ways of thinking about connections between climate change and rural child health, all contributing authors were also asked to draw on the relevant body of research evidence to provide considered scholarly discussion of these connections.

The principal audience for this book will be researchers, practitioners and health policy-makers around the world wanting an overview of some of the key issues for rural child health in a climate-changing world. The editors have tried to ensure that the needs of both the developed and developing world are included in this volume, but we emphasise that we have done no more than sample from a vast range of possible issues and geographies. Thus, the collection should work as an introduction to some of the effects of climate change on rural child health for those who are fairly new to climate change research. This includes policy-makers in regional and national government departments of health considering how to include a rural child health focus in climate change policy and programs.

A COLLABORATIVE PROJECT

This project has been led by an editorial team comprised of a senior academic staff member from the University Department of Rural Health (UDRH) at the University of Tasmania (UTAS), a clinical director from a rural general practice in Tasmania, and a specialist in pediatrics at the National Institute of Child Health and Human Development (NICHD-IL) in Israel.

The involvement of the UDRH allowed for broad knowledge about rural health to inform this project. The multidisciplinary UDRH in Tasmania is committed to improving access to health care resources and contributing to improved health outcomes for people in rural and remote areas of Tasmania by:

- Working collaboratively to achieve an adequate, appropriately trained and stable rural health care workforce;
- Facilitating access to appropriate education and training opportunities, resources and ongoing support across the learning continuum, and
- Promoting and supporting a primary health care approach to rural health research and preventative health strategies (http://www.ruralhealth.utas.edu.au/about).

The involvement of a Tasmanian rural general practitioner with postgraduate research qualifications in pediatrics meant that this project benefited from practitioner involvement, not just university department involvement. As the chapter on the effects of the global financial crisis and climate change on rural child health in Australia notes, Tasmania leads all Australian states in loss of farm income due to drying conditions. This has had important impacts on these communities that have not yet been translated into research and policy. Yet health practitioners from such regions, especially family practitioners in the 'frontline' of primary healthcare, are well acquainted with the health effects that climate change has brought. This remains so regardless of whether one agrees such changes in climate are anthropogenic or not. In a translational research project of this kind it has been particularly important that there be primary healthcare practitioner involvement and editorial leadership from rural regions.

The involvement of a specialist in pediatrics from NICHD-IL has helped give this volume a critical cross-cultural and international focus. The NICHD-IL operates as a virtual institute under the auspices of the Medical Director, Ministry of Social Affairs in order to function as a research arm for the Office of the Medical Director. It has produced hundreds of national and international collaborative research outputs as part of its mission to further interdisciplinary study on many aspects of public health and human development. Many of these publications take a strong focus on the particular needs of disadvantaged children. The work of the NICHD has also offered an important model of how researchers from different cultures and systems can collaborate on issues to do with child and adolescent health. This project has greatly benefited from the support of the NICHD in meeting the complex challenge of interdisciplinary research on climate change and rural child health.

Finally, but most importantly, this book would not have been possible without the contribution of Sarah Brinckman who provided research assistant support to the project from its inception to its conclusion.

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Chapter 1

CLIMATE CHANGE IMPACTS WILL BE PERVASIVE

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Even though the reality of climate change is becoming more and more apparent, international actions to slow its accelerating pace seem to moving more and more slowly. As a consequence, on local to global scales, society, its managed systems, and the natural environment are going to face larger and more rapid changes in climate and the availability of ecosystem services than over at least the whole course of civilization. The effects will be pervasive, causing not just direct effects from the changes themselves, but also through indirect pathways as adjustment leads to further adjustment in an ongoing and continuing manner. For some of the environmental changes, various adaptive measures can moderate the impacts; for many other changes, however, especially those affecting the very young and the vulnerable, forced adjustments will involve increased suffering and dedication of a larger and larger share of available resources to sustaining one's current standard-of-living, leaving a shrinking share for building a better future.

INTRODUCTION

Climate change and associated impacts will affect everything and everyone—the young and the old, the healthy and the infirmed, the rich and the poor, some by a little and some by a lot. While some of the changes, like more intense heat waves, will affect us directly, many of the impacts are likely to be experienced through impacts on the natural world on which we depend. Although preparation and adaptation can moderate some of the impacts, new ones are likely to arise as the global energy system is changed to limit emissions of the gases and aerosols that cause climate change. A few of the changes may lead to local opportunities and gains, but many are likely to result in negative consequences, many arising because the extremes that already impose costs will occur more frequently and be even further from the norms to which society and the environment have become reasonably adapted.

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BACKGROUND

As described in detail in the Fourth Assessment Report of the IPCC (1), the composition of the Earth's atmosphere is being dramatically changed. Human-related emissions of carbon dioxide (CO_2), primarily as a result of combustion of fossil fuels (coal, oil, kerosene, and natural gas) and destruction of forests, have increased the preindustrial CO_2 concentration by almost 40%; a significant fraction of this perturbation will persist for millennia. Emissions of methane (CH_4) and other gases and aerosols, primarily as a result of agricultural and industrial operations, inefficiency, and polluting activities are also significantly affecting the natural atmospheric abundance of these species. The additional trapping of heat radiation by these higher concentrations amplifies the intensity of the natural greenhouse effect, leading to global warming. Since the start of the Industrial Revolution, the global average of local changes in near-surface air temperature (referred to as the change in the global average temperature) has increased by about 0.8°C.

While this amount of warming has required some adjustment, much greater warming lies ahead. As atmospheric composition has changed, the large heat capacity of the ocean has held the warming to about 0.5°C below its expected value. In addition, emissions of sulfur dioxide from the tall stacks of coal-fired power plants have led to an increase in sulfate aerosol loading that is temporarily delaying a further warming of about 0.9°C. Although a total potential warming of 2.2°C may seem a small change at a particular location, warming of the world by this much is more than a third of the increase in global average temperature since the Last Glacial Maximum about 20,000 years ago. In terms of the variations in global average temperature over the last 2000 years, a 2.2°C warming is several times as large as the average variations that have occurred as society developed over this period. That roughly half of the human-created warming influence will persist for at least centuries is likely to be particularly disruptive. As Nobelist Paul Crutzen has noted (2), we are moving from the Holocene (the relatively stable, post-glacial climatic state prevailing for the last 10,000 years) to the Anthropocene (a warmer period characterized by human influences on the climate).

And this is just the warming caused by past emissions. Fossil fuels presently provide about 80% of the world's energy. Even if international leaders were able to agree on aggressive emission control measures, decades will be required to cut emissions by enough to stop further climate change. As a consequence, results from climate model simulations carried out by groups around the world project that human-induced global warming will reach roughly 2.5 to 4°C above its preindustrial level by 2100, with more warming beyond unless stringent emissions controls are put into effect over the next few decades.

WEATHER CHANGE, NOT JUST A FEW DEGREES

Focusing on the often-used metric of change in global average temperature can be seriously misleading. First, all model simulations project that the temperature increase will be larger over continents where people live than over the oceans, larger in mid-to-high latitudes than at the equator, larger at night than during the day, and larger during winter than in summer, except where land areas dry out and drought results. The larger change over land is accompanied by a corresponding increase in the absolute humidity, leading to an increased likelihood of heavier precipitation and to significant increases in the heat (or discomfort) index in regions that are already warm. The more moderate warming in low latitudes is a result of an increased share of the trapped energy being used to evaporate water, mostly from the oceans, providing additional water vapor that strengthens tropical cyclones and other storms. The larger increases at night make heat waves greater threats to human health because of the reduction in nighttime cooling. Larger warming in winter than summer leads to higher survival rates of pests and disease vectors, increasing the likelihood of human disease and ecosystem loss due to pests and wildfire. Indeed, winter minimum temperatures will kill fewer people and flu may be less prevalent, but overall, the general health effects of climate change are very likely to be negative (3).

Focusing on the slow, projected changes in global average temperature also obscures the changes in weather that are actually experienced. Weather is the instantaneous state of the atmosphere, ranging from fair to stormy, with which we have to contend, whereas climate is the multi-decadal average of the weather (including the higher statistics of its behavior). Climate change will bring new high temperature extremes, longer and more intense heat waves, faster soil drying and more rapid onset of drought, heavier precipitation and more intense and longer-lasting storms, earlier melting of snow and ice, and more. Basically, as the intensity and frequency of weather extremes increase, the likelihood of weather conditions that lead to damage, injury, and even death will increase. These changes will be felt particularly in vulnerable regions, including communities and locations near rivers (which are likely to experience more frequent and intense floods that carry more soil and pollutants into river basins), coastlines (which are likely to be altered by increased coastal erosion and the inundation forced by sea level rise and stronger storms), seasonally arid areas (which are likely to experience reductions in water resources, earlier drying, and increased likelihood of wildfire), and water scarce regions (which are likely to be impacted by reductions in springtime snowpack coupled with increased summer demand and lower water quality). The Working Group II report of IPCC's Fourth Assessment Report (4) provides a global and sectoral summary.

REGIONAL VARIATION

Because those in rural areas are often more involved in outdoor activities such as farming, forestry, tourism, recreation, and natural resource extraction, the impacts of climate change on the health and well-being of those in rural areas are likely to be particularly problematic. The young and the elderly will be especially at risk, their adaptive capabilities and resources generally being more limited and dependent on others than the population as a whole. While climate change is best evaluated and projected starting at the global scale, most impacts and consequences must be evaluated and projected starting at local and regional scales. Even in a nation as seemingly developed as the US, there will be different consequences in different regions, necessitating different adjustments and adaptations (5-7); similar complexity exists across the world.

Both particular weather events and their average characteristics over time (i.e., the climate) determine land cover. As a result, changes in weather and the climate (and in the CO_2 concentration) will cause changes. Over decades, prevailing land cover will change in type and character, with traditional plant species generally dying faster than new species grow to replace them. More intense storms are likely to cause higher flood levels and greater wind damage, increasing the likelihood of injury and death in the absence of greater protection. More intense periods of dry weather will increase the likelihood and severity of wildfires and health impacts of smoke. While the effects of heat waves in urban areas can in many situations be dealt with by expanding air-conditioning, the greater prevalence of outdoor employment and the older and more open homes inhabited by the less affluent in presently warm, rural regions are likely to substantially raise the costs and limit the effectiveness of an air-conditioning strategy. At the same time resources are needed to pay for adaptation, global warming in many areas will adversely impact outdoor, job-creating activities like construction, tourism, and farming.

Health will also be impacted less directly. Warming will increase the prevalence of weeds, pollen, invasive species, and mosquitoes and other disease-bearing vectors, increasing the incidence of asthma, allergies, disease, and other adverse health outcomes that disproportionately affect the young and old. Existing ecosystems will be stressed and the ranges of individual species will shift, forming less coherent, shifting ecosystems in which opportunistic species will win out, likely leading to reductions in vital ecosystem services. Facing many new and unaccustomed threats, parents are likely to be more stressed themselves and less knowledgeable about the emerging environmental threats facing their children, imposing greater demands on health providers.

Because those in rural areas tend to be more involved in activities directly coupled to the environment than those in developed areas, the impacts on the environment are very likely to have greater consequences. Those in agriculture will need to be constantly adapting their practices and crops to take advantage of the changing weather patterns, available water resources, and changing soil characteristics while minimizing losses to a changing mix of pests and weeds, and doing so in ways that make economic sense as their competitors are also adapting to changing conditions. Those familiar with the ins and outs of growing the widest set of potentially suitable crops and having the resources to invest in adapting their capabilities and infrastructure (e.g., storage facilities, etc.) will do best; those who fail to start making needed changes until the yields of their present crops are persistently impacted will fare worst, affecting not only themselves, but extending economic losses to the surrounding community and future generations.

Tourism and recreation, which are often important sources of income in rural areas, are likely to be seriously impacted. Higher snowlines, thinner lake and river ice, and shorter periods of cold will shorten the period for winter recreation, and a poleward shift of the ice storm belt is likely to more frequently disrupt unprepared regions. In some regions, expansion of recreation activities during longer warm seasons may compensate, although more frequent and intense summertime dry periods can mean that campgrounds and forests are more frequently closed due to increased danger of wildfire. Earlier periods of snowmelt and longer periods of low river flow are also likely to reduce options for summer water-related activities.

INDIGENOUS PEOPLES

For indigenous peoples, changes in climate can lead to shifts in the dates of emergence of vegetation, harvest of crops, migration dates, and reproduction of wildlife, thus altering traditional calendars and outdating the empirical knowledge that underpins the wisdom of elders and on which social structure, and therefore community well-being, can depend (8). For Native Americans and others forced onto specific lands, the adaptive approach they have relied on for millennia to deal with environmental change, namely relocating to find needed and sacred resources, is no longer an option, upsetting societal relations and cultural practices.

Those in the Arctic face the most immediate threat (9). Retreat of sea ice leads to erosion of the barrier islands and other coastal locations where many indigenous communities were established to conveniently harvest resources from both land and ocean. Roughly 150 indigenous communities in Alaska alone are going to need to be relocated—and, because both homes and community infrastructure must be relocated, the estimated cost is $0.5-1.0M per person (10), resources these communities do not have. Sea ice retreat also complicates harvesting of marine mammals for food while permafrost and melting of river ice make both summer and winter movement more difficult. Those in these communities are concerned that climate change will destroy their indigenous cultures by disrupting the community-wide sharing of responsibility and harvests from hunting and fishing that have sustained them through harsh winters for the many millennia they have lived far to the North.

Those in other regions will also face relocation. In Louisiana, for example, over 60 square kilometers of coastal lands are being lost every year, at this time primarily due to river channeling rather than sea level rise (7). Seeking to recruit a young girl to college, a professor asked her grandmother about their family history. The grandmother's parents cut trees in the forest and made furniture to sell in New Orleans. By the time the grandmother was grown, the forest was gone and she and her husband farmed the land and sold the harvest in New Orleans. The land is now too wet for her children to farm, so they catch crawfish and sell them in New Orleans. With continuing coastal erosion, the land will be gone by the time the granddaughter is grown. What will it mean when one's home community no longer exists? What will it mean for all those around the world who will be forced to migrate to escape expanding deserts as the subtropics expand? Attachment to one's homeland seems basic and ubiquitous—what will be the consequences of an increasing number of people losing their homeland—at least as how they knew and survived in it? As people live longer, how will living in a rapidly changing world affect the sense of security and reassurance that home regions and home populations provide?

COMMUNITY SUSTAINABILITY

The longer-term changes in the natural environment will also complicate efforts to meet the Millennium Development Goals to which emerging nations are committed in order to move toward a more sustainable interaction with the environment and natural resources (11,12). Ensuring clean water may well become more difficult as more rapid evaporation reduces available supplies at the same time that population is increasing and urban demand for water is growing. Less frequent, but more intense, convective precipitation is likely to increase runoff of wastes and soil erosion, polluting rivers and more rapidly filling reservoirs with silt. For those in northern regions, wintertime warming may lead to savings due to the reduced need for fuel, but in most regions, warming is likely to increase the need for costly air-conditioning. While biofuels can be used to overcome cold, using these fuels to overcome heat is much more difficult, often requiring community-wide electrification. For the young, the increasing heat stress and more prevalent disease vectors are likely to make it more difficult for health providers to reduce childhood death and disease.

Consequences for sustainability will also be indirect. Adaptation to climate change is likely to require knowledge that reaches beyond the bounds of human experience, and so outside the bounds of traditional knowledge. No longer will village elders be able to suggest adaptive steps based on past experience; now, younger people, who tend to be both more creative and better educated, will be more likely to have the answers, thus disrupting the glue that has provided intergenerational binding. At a "wisdom circle" that I participated in on the most important environmental changes affecting Native Americans in the northeastern US, I would not have guessed that PCBs in the stream and river sediments would have been viewed as the most critical issue (13). This was the case not mainly because the fish could no longer be eaten nor because of the economic cost of replacing this food source, though both were important, but because the time spent fishing after school for the evening meal was when father or grandfather got to sit with the next generation to orally pass along the traditional knowledge and unwritten wisdom that define social structure, norms, and mores. The PCBs thus upset the passing along of what it meant to be a Native American, and, in the view of the elders I heard, it was the PCB pollution that was responsible for the rebellion of the younger generation and breakdown of intergenerational linkages.

CONCLUSIONS

In urban settings, friends and electronic media rapidly pass along information about how best to adapt to new and changing conditions. In rural areas, however, success, and even survival, requires a close understanding of how nature works. With climate change affecting all the rules, however, those tied to old, empirically derived rules are likely to fail to adapt soon enough, and those seeking to gain new insights will be faced with a continuously changing situation, locally and beyond. For the young, and those of all ages, replacing stability and confidence in understanding with constant change and uncertainty is not likely to be without consequence.

At the same time as the environment around those in rural regions is changing, so will the demands and expectations being placed on these regions and those in them. Moving away from fossil fuels, with their dispersed mines and oil fields, will be replaced with demands for renewable energy. Because such energy is much less concentrated than fossil fuel energy, more space and different space will be needed. For American Indian tribes whose reservations were often located on some of the least desirable lands—that is, in very sunny or very windy environments—these attributes may ironically turn out to be the most sought after for the new energy economy, creating a potential new source of income. For most, however, what is going to be required is additional training in order to become proficient in the new green industries. For those who are now adults, further education can be a challenge, and so it my be that many end up not well-suited for the new economy, weakening economic and community well-being. If the deteriorating conditions then further impact on the education of upcoming generations, rural areas could cascade toward collapse.

What is most clear is that adapting to both the changing climate and the new economy is going to require a well-educated and informed populace. The key component will be ensuring a strong educational system for young people, even in, indeed especially in, the communities that are struggling the most. While the young are thus likely to be among the most vulnerable, they are also likely to be the key to being successful in the rapidly and constantly changing world that likely lies ahead, especially if they can be connected to the Internet and its learning resources.

We are only beginning to appreciate the complexity, depth, and breadth of the changes and impacts that climate change will initiate. Understanding will only come when knowledge about climate change can be widely disseminated and communities can together explore the potential impacts from near- to long-term, including especially the intergenerational and societal ties being stressed and even broken.

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Chapter 2

CLIMATE AND CHILD HEALTH IN RURAL AREAS OF LOW AND MIDDLE INCOME COUNTRIES

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Children are amongst the most vulnerable to climate change because they currently experience a high health burden from climate-sensitive diseases. Rural populations in low and middle income countries are also vulnerable to climate change impacts because of a high dependency on local environmental resources. We investigated the evidence base for the direct impacts of current climate factors on child health using a systematic review of studies quantifying an association between temperature and/or rainfall and child health outcomes. We found 35 papers that met our criteria, which were classified as spatial or temporal analyses. There is good evidence that climate factors (temperature and rainfall) affect the spatial and temporal distribution of malaria. There is also good evidence that temperature and rainfall are an important determinant of diarrhoeal disease morbidity, reflecting both acute mechanisms (e.g. short term water contamination) and long term effects (chronic water scarcity). The review highlighted that little is known about the specific mechanisms that link climate patterns with disease or mortality. Few analyses were of high quality, which would include adjustment for spatial or temporal confounders. Many studies did not distinguish between seasonal and other climate effects making interpretation difficult. There is a need for more research to describe the mechanisms by which climate variability affects child health. To identify those communities most at risk from future climate change we need both to improve the understanding of the epidemiology of disease and identify interventions to lower the impact of the changing climate. [250]

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INTRODUCTION

Children, representing a third of the world's population, are amongst the most vulnerable to climate change because they currently experience a very high health burden from climate-sensitive diseases (1). Children will be exposed to climate change through changing weather patterns (more intense and more frequent extreme weather) and though changes in water and food quality and quantity, ecosystem services and, most importantly, impacts on livelihoods and income. Despite the growing importance of climate change, there has been relatively little research on the wider environmental and social determinants of many of the important climate-sensitive diseases. Such information is required to underpin assessments of vulnerability and inform adaptation policies.

Observational studies of climate effects require the most appropriate characterization of the climate exposure. "Weather" is the state of the atmosphere at a given time and place, in terms of temperature, moisture, wind velocity, and barometric pressure variables. Weather varies from day to day. "Climate" is defined in terms of the mean and variability of the relevant meteorological variables over a period of time ranging from months to thousands of years (2). The period for defining a climate is three decades, as defined by the World Meteorological Organization (WMO). In simple terms: climate is what you expect, weather is what you get. Climate variability occurs at various temporal (season, year, decade) and spatial scales and is an inherent characteristic of climate whether the system is subject to change or not. Observational climate-health studies can be categorized into the following types:

- Health impacts of individual extreme events (heat waves, floods, storms, droughts).
- Spatial studies, where climate is an explanatory variable in the distribution of the disease or health-related outcome.
- Temporal studies (time series)
    - inter-annual climate variability
    - short term (daily, weekly) variability (weather)
    - longer term (decadal) variability (of interest in the context of detecting early effects of climate change).

In this paper, we investigated the scientific evidence base for the "direct" impacts of current climate on child health outcomes using a systematic review of epidemiological studies that have quantified the association between climate/weather factors and child health outcomes. We will then discuss these findings in terms of the future implications for climate change and make recommendations for further research.

LITERATURE REVIEW

A comprehensive literature review was undertaken to identify published studies that described the relationship between weather and climate factors and child health outcomes. Although there are many descriptions of the seasonal patterns of disease and mortality in the literature, these were not included in the study because they provide only limited information on the specific effects of meteorological factors and provide little insight into mechanisms. Similarly, studies of the health impacts of individual weather-related events (e.g. floods, heat waves) can only provide limited information about the effects of temperature and rainfall on health outcomes.

Search strategy

The following databases were searched: Embase, Medline, CAB abstract, Global Health, Popline and Web of Science. The reference lists of key papers were searched in order to find additional papers. We also searched the websites of international agencies including World Bank, WHO, FAO, and UNICEF for relevant research reports. Full list of keywords and MESH headings are in listed in Annex/Supplementary material.

Annex/Supplementary material

(temperature OR rain* OR precip* OR flood* OR drought* OR climat* OR meteorolog* OR weather OR extreme event OR dryland* OR heat OR heatwave OR cold OR disaster OR cyclone OR hurricane OR typhoon OR monsoon OR ENSO OR el nino-southern oscillation OR tropical storm).mp
AND
(malaria OR dengue OR trypanosomiais OR rift valley OR schistosomiasis OR helminth* OR river blindness OR leishmaniasis OR lyme disease OR hantavirus OR hemorrhagic fever OR trypanosomiasis OR yellow fever OR diarrh* OR cholera OR shigella OR typhoid OR salmonell* OR rotavirus OR campylobact* OR Escherichia coli OR buru* OR communicable disease OR infectious disease OR gastrointestinal OR dysentery OR giardia OR hepatitis A OR malnutrition OR stunting OR wasting OR micro-nutrient deficiency OR nutrient deficiency OR undernutrition OR hunger OR drown* OR injur* OR ear infection OR dermatitis OR conjunctivitis OR trachoma OR death OR mortality OR morbidity OR hypothermia OR hyperthermia).mp
AND
[all child under 18] (child OR infant OR adolescent)
AND
Low and middle income country (according to World Bank definition)

Inclusion criteria

- Published between 1 Jan 1970 and 1 October 2009
- Peer review journal papers. Grey literature was only included if it was adequately peer reviewed.
- Epidemiological or observational studies that report quantitative measure for an association with a climate or weather exposure and a specific child health outcome.
- Epidemiological studies of sufficient quality with respect to the study design and exposure/outcome measurement.
- Studies in low and middle income countries only, based on the World Bank definition (3)
- Studies that included rural health outcomes (however, we did not exclude studies that included both rural and urban populations and these were considered on a case by case basis).

- Studies that included health outcomes in children aged 0 to 18 years.

Exclusion criteria

- Mental health, psychological or psychosocial outcomes
- Respiratory disease outcomes
- Studies that looked at migration or population displacement as the exposure, whether linked to a climate event or not.
- Studies that used an environmental exposure as the exposure, even where these were closely climate-related.
- Studies that report only seasonal patterns or rates by season or calendar month but do not quantify the association between a climate/weather parameter and health outcome.

An initial search was conducted and the references were integrated into a single database. After the duplicates were removed, titles were scanned initially and then title and abstract were screened in order to include only those that met the inclusion criteria. Due to the large number of papers that included mention of respiratory diseases, we excluded this outcome.

WHAT WE FOUND

The initial search elicited 4,551 papers (after removal of duplicates) which was reduced to 941 after scanning the titles. We found 35 papers that met our criteria. There were many studies that reported only seasonal patterns and these were excluded as they did not explicitly model rainfall or temperature exposures. Of the studies that quantified an association between climate and child health, we classified them into two main types: cross-sectional or spatial studies and temporal or time series studies. The latter were subdivided into daily/monthly time series and annual time series studies.

We found no studies that examined the effect of climate factors on child growth (anthropometric measures), malnutrition or micro-nutrient deficiencies. Although we excluded several studies that reported child growth impacts associated with a weather-related disaster (flood or drought). Such event studies rarely have control (pre- or post event) periods and so can over-estimate the impact of an event. The objective of this review was to understand the impact of average climate and weather conditions, and not impacts associated with extreme events or disasters that often have significant non-climate causes.

Cross sectional studies – climate factors that determine disease distribution or prevalence

The majority of studies investigated the effect of climate variability across space (17 studies, see table 1) where climate factors were a determinant of the geographical distribution or the prevalence/incidence of a disease. Mapping of many vector borne diseases and/or their vectors has been rapidly advanced by improvements in computing and GIS software, as well as in the geo-referencing of disease and exposure data (4). The majority of studies were on malaria (four studies (5-7)) which has now been extensively mapped in sub-Saharan Africa. The geographical distributions of diseases that are transmitted by cold blooded vectors or rely on cold-blooded hosts (e.g. schistosomiasis) are ultimately limited by temperature.

The studies used both instrumental data (from weather stations) and remote sensing data to determine the exposure. The spatial resolution of the exposure variables ranges from detailed local measurements to "out of sample" interpolation of weather stations using GIS software. No studies estimated the measurement error associated with interpolation methods. The distribution of weather stations varies by country, with many low income countries having insufficient coverage.

The cross-sectional studies used averaged measures of temperature and rainfall over the specific time periods- but no studies included data for more than 30 years. Therefore, strictly speaking, the exposure was not the local "climate" but a proxy measure. For convenience in this paper, we have used the term climate to describe these "longer term" exposures.

Table 1. Cross sectional studies of climate and child health.

Population, Area	Exposure	Health outcome	Methods	Results
3 towns: Nourna, Cisse, Goni in Burkina Faso[5]	Rainfall, temperature Dec 2003-Nov 2004.	Malaria	Logistic regression. temperature, relative humidity, rainfall in previous month, interaction terms, several transformation functions tested. Adjusted for sex, age, use of bednet, type of house, presence of well, presence of farm, presence of animals, presence of mosquito.	Association with mean temperature (coef:-86.9 CI: -113; -60). The effect of interaction was small. Relationship between temperature and malaria is non-linear. Effect of rainfall only above 100mm per month (lag of one month). The RR at 150mm was 0.3 compared to 0.70 at 160mm. 55% relative humidity, the risk was 25% lower than at 60% relative humidity. Risk increase exponentially at relative humidity > 60%.
Kenya [6]	Fuzzy model of suitability (FCS)	Malaria - Community based parasite prevalence surveys	217 independent parasite surveys. The MARA project uses the climate-driven fuzzy model of suitability (FCS) used to predict Malaria prevalence map. The climate parameter is included and FCS categorizes the climatic condition b/w suitable and unsuitable. Adjusted for: end-year of the study, survey sampling methodology, max age.	The FCS produce a weak positive correlation: R square: 0.364, p<0.0001), similar results after controlling for others variables, though no value reported after adjustment.

Table 1. (Continued).

Northern Malawi [7]	Total annual precipita-tion, max annual temperature, altitude.	Malaria Incidence Children under age of 5.	soil water holding capacity, Collinearity analysis. Bayesian Poisson regression models.	No effect of temperature. Malaria Incidence associated with altitude, precipitation (marginally associated; RR 1.031, 95% interval 0.0.950-1.120) and soil water holding capacity.
North-eastern Tanzania [32]	Average daily mean temperature Rainfall	Malaria prevalence (1-45 yrs)	2 cross-sectional surveys in 6 altitudes transects. Logistics regression. Adjusted for altitude, age, sex	Rainfall correlated with parasite prevalence. For every 100mm increase in rainfall, the OR of parasitemia was 0.54 (95% CI: 0.42-0.71, p <0.001)) in Kilimanjaro.In Tanga no stats significant.
Global, 140 populations [45]	Heat index	Birthweight (WHO database)	Correlation, Regression. Adjusted for: humidity, SES, diet intake, IM, GDP, price, exchange rate, maternal height, Latitatude/longitude	2.7 per cent increase birthweight per unit decrease in heat index (causation not proven)
Mali [16]	Rainfall, temperature humidity,is ohyet class	Active trachoma and triachiasis Children <10 years	Logistic regression. Adjusted for age, ethnic group, lat , long, facial dirtiness, flies on face, distance to water supply.	Active trachoma associated with mean temperature >31 degree : 1.17 OR p=0.026 compared to mean temperature <31 degree
Burkina Faso [11]	Monthly rainfall	Mortality Children <5 1970-1998	Event history analysis (discrete time event history model) Interaction B/w rainfall condition and agro-climatic region, time-varying covariate weather variables Adjusted: age, birth order, cohort, mother's age, multiple births, mother's education, season of birth.	Significant effect for Yearly deviation and long term average (interaction). In period of severe drought (<85% of normal rainfall) children living in the 900mm and over region have lower risk of dying than children living in the 500mm-699mm region. OR: 0.48 P<0.05 for 1-59 months; OR: 0.35 P=0.05 for 7-17 months). In the 500-699mm region, the risk of child mortality is reduced (OR: 0.63 p<0.05) when more than 85% of the normal amount of rain falls during the year. While in wetter region (900mm and over) the risk of dying is higher (OR 1.89 P=0.10) when recent rainfall is more abundant (more than 85%). (OR: 3.01 P= -0.05 for children 0-6 months)
Colombia [12]	Annual temperature	Child mortality	Regression model. Adjusted for: mother's age; mother's education, FP activities, availability of medical service, transportation, local price of food.	For rural women over 25 years old there is a quadratic relationship between temperature and child mortality ratio which peaks b/w 22 and 24 degree.

Table 1. (Continued).

Senegal [13]	Monthly rainfall data. 33 rainfall stations, cases matched to the nearest station	Child mortality (DHS data)	Dynamic model of joint determination of fertility and mortality (by month), bivariate random effect probit model. Adjusted for: women's age, multiple births, sex child, mother's education, month of birth, region, seasonality (month fixed effect and historical mean rainfall).	If rainfall is better than average 12 months prior conception increase the probability of child survival, condition al on the prior fertility state. Actual rainfall (12-23 prior, Coeff 0.087, t: 1.360). Positive income shocks, perhaps induced by advantageous weather shocks, may enhance the probability of child survival during dangerous first months of life.
Benin, Burkina Faso, Cameroon, Ivory Coast, Ghana, Guinea, Mali, Niger, Senegal, Togo. West Africa [33]	Average monthly rainfall 1997-2001	Child mortality (DHS data)	Generalized linear model Adjusted for maternal education, birth order, age, incidence of diarrhoea, population density, urban proximity, coastal proximity, distance to roads, farming system, arid zone, growing season, Stability of malaria index.	Children living in an area with less than 2ml of daily rainfall, the probability of survival after 59 months is 86.5%, whereas for children living in a areas with more than average daily rainfall stand 92%-93% chance of surviving after age 12 months.
Western Ivory Coast [15]. Several school locations	Rainfall (satellite data) NVDI, temperature 2001- 2002	Schistosomias (6-16 years epidemiological survey, 3818 children)	Cross-sectional logistic geostatistical model, MCMC simulation to estimate spatial parameters. Adjusted for: age, sex, SES, travel distance to nearest facility, elevation, soil type, land cover, slope, distance to water bodies	Rainfall and temperature -no effect Elevation was significant (>=400: OR 0.22, CI: 0.08-0.54, ref. <400). SES was more important to than environmental data.
Ogun state, Nigeria [17]	Rainfall, temperature (remote sensing data), NDVI	Urinary Schistosomiasis (question-naire)	Binary logistic regression models. Development of spatial risk map.	LST (temperature) -0.478, p=0.035 Rainfall: -0.006, p=0.0005.
2 climatic region, Caribbean coast, highland, Colombia [8]	Rainfall, temperature	Infectious acute diarrhoea in under 5 (hospital admissions)	Bivariate analyses.	Rotavirus: temperature: IC: 0.04-0.23, p=0.000 Humidity: IC:0.04-0.23, p=0.000

Table 1. (Continued).

Kwazulu-Natal, coastal South Africa [10]	Annual and seasonal rainfall and temperature	Helminth infection in children	Univariate, Step-wise multiple regression: bw rainfall related variables Mean daily maximum (MDmax), Mean daily min (MDmin), mean annual temperature (MAT), Mean Annual (MAP) and monthly precipitation (MMP). Wetness index (HU)	T. trichiura MAP b=0.021 R2=0.2949 *Necator americanus*: related with temperature –derived variables, MDmin for January largest contribution (MDMIn, B=15.585, R2=.738, p=0.0015). *Strongyloides stercoralis*, correlated with two temperature vars and one rainfall(MAT and HU dominating) MAT: b=13.478, r2=0.629, p=0.0001 HU b=-0.057, r2=0.269, p=0.0025 *Ascaris lumbricoides* : 2 rainfall-derived variables (MMP for july and MAP) MMP for july B=0.349, R2=0.5249, p=0.0178), MAP b=0.036, r2=0.1802, p=0.0644)
Tunisia [14]	Rainfall, temperature	Leishmaniasis in < 5 years. Medical records	Spatial autocorrelation, spatial Poisson regression. (geoRglm)	Temporal trends seems to be influenced by climate, a rainy year is followed by 2 years later by a high number of cases. Annual Rainfall value for 2 years before: Positive correlation 0.87. Districts considered as hotspot had annual rainfall of 495mm and a semi-continental climate 30 degree. Regression is report but not clear results
18 Pacific Islands [9]	Rainfall, temperature	Annual incidence diarrhea	Cross sectional study, adjusted for GNP, geology, Pearson correlation.	Positive association between temperature and diarrhoea. R^2: 0.49 p<0.05)
Global [46]	Average rainfall & temp.during survey periods	Diarrhoea prevalence in kids (in high quality studies)	Cross-sectional study, adjusted for income and water/sanitation coverage	4% increase in diarrhoea incidence (1–7%, p = 0.02) for each 10 mm mo–1 decrease in rainfall. Association with air regions (climate type) not significant

The complexity of the modelling approach varied greatly from study to study. Some authors analysed the bivariate association without adjusting for confounders (8-10), but others appropriately modelled the risk of disease or mortality by adjusting for confounders and exposure to specific weather patterns (11-13). A few authors modelled the spatial patterns of the data using more sophisticated spatial statistics (14-16).

The majority of studies were on malaria or all cause mortality and were in Africa.Overall, there was very good evidence that, at the continental scale, climate factors (temperature and rainfall) are important determinants of malaria. The evidence for schistosomiasis is less clear. Of two studies (15, 17), one did not find any statistical significant association with meteorological variable, but the level of schistosomiasis varied by elevation. Children living above 400m were 80 % less likely to get schistosomiasis than those living below 400 meters. The other study only found a weak association with rainfall (17).

Studies that looked at the climate determinants of diarrhoeal disease prevalence found that areas with less rainfall, in general, had a higher prevalence of disease. For example, Lloyd et al (12) found that the incidence of diarrhoeal disease increased by 4% for each 10mm decrease in rainfall. A study in the Pacific Islands found a similar effect although it was not statistically significant.

Time series studies that quantified short term associations between weather and health

We found 13 studies that quantified a short term (acute) association between temperature and/or rainfall and health outcome (daily, weekly or monthly disease incidence or counts) (see table 2). Only few of them adjusted for time varying confounders in their analysis, particularly season, and therefore the results were difficult to interpret (see below). The studies addressed the following health outcomes: malaria (18-21), meningococcal meningitis (22-23), dengue (24), all cause mortality (25), diarrhoeal diseases (9,26-27), helminth infection (28) and leishmaniasis (29).

Table 2. Daily and monthly time series studies of weather and child health.

Population, Area	Exposure	Health outcome	Methods	Results
Song Yang district, Thailand [19]	Rainfall 2000-2002	Malaria cases	Monthly data correlation, regression. Adjusted for: age, sex, pregnancy, population movement	Rainfall negative correlated with the proportion of patients with hyperparasitaemia (-0.59, p<0.001) and proportion of gametocyte carriers among plasmodium falciparum. Adj OR for hyperparasitaemia: 1.6 (95% CI 1.14-2.2; p=0.006) Adj OR for gametocyte carriers 1.3 (95% CI 1.03-1.6; p=0.02).
Rwanda[18]	Rainfall and temperature (monthly)	Malaria 1961-90	Monthly time series analysis (ARIMA)	Pronounced sensitivity to temperature. LnI_m=-4.32+1.64lnTn_{m-1}+0.83lnTn_{m-2}+5.34*$10^{-4}R_{m-2}$ (0.70-2.56) (0.12-1.78) (0.04-10.3) +7.7+$10^{-4}R_{m-3}$ (2.8-12.6) Min temp was significant (but not max or mean)
Gash Barka and Anseba, Eritrea[20]	Rainfall	Malaria cases by district 1998-2003	Poisson regression model adjusted for season, NDVI (NOAA), impregnated net, larval control.	Increased numbers of cases were significantly positively related to differences in the amount of rain 2 and 3 months previously: 1 standard deviation increase in the sum of rainfall in the previous 2-3 months increase incidence of malaria by 3.4% in Gash but it decrease the incidence in Anseba.
El Oculto and Aguas Blancas Northern western Argentina [21]	Rainfall, temperature humidity, Dec 2001-Nov 2005.	Malaria	Random effect Poisson regression [Unit of analysis?- annual]	1 degree increase in the maximum mean annual temperature, the risk of transmission increase by 33% (p=0.003). One increase in 1mm in the mean annual rainfall increases by 0.1% (p=0.001). Aguas Blancas: in the final model Humidity, temperature: One unit increase in temperature IR increase by 59% (p=0.004). 1% increase in humidity malaria risk increases by 1% (p=0.023)

Table 2 (Continued).

Matlab, Bangladesh [25]	Temperature Jan. 1994 to Dec. 2002	Mortality [DSS: mortality] .	Generalized linear Poisson regression model of daily time series. Adjusted for: seasonal variation, between year variation, holiday, day of week.	Every 1 degree decrease in mean temperature was associated with an 11.1% (95% CI: 2.4-20.7) increase in all-cause mortality. In adults 3.2% (95% CI: 0.9-5.5). No effect of high temperatures.
Fiji [9]	Rainfall, temperature 1978-1998	Incidence of diarrhoea (Monthly reports)	Poisson regression monthly data, controlling for season.	3% increase in diarrhoea per degree increase in temperature in the previous month. Diarrhoea increased by 8%(7.6-9.2%) per unit decrease in rainfall below $5x10^{-5}$ kg/m2/min. (the effect persisted with lag effect, previous month data). Diarrhoea increased by 2% (95% CI: 1.5-2.3%) per unit increase in rainfall above $5x10^{-5}$ kg/m2/min.
Indonesia [26]	Rainfall, temperature 1993-1999	Cholera - hospital based and outbreaks	Bivariate	Different effect of rainfall and disease prevalence in different location.
San Sebastian, Southern Brazil [24]	Rainfall, temperature	Dengue (reported cases)	Spearman correlation, time lag.	Rainfall2nd month: R2: 0.56, p<0.001 3rd month: R2: 0.68, p<0.001 4th month: R2: 0.69, p<0.001 Temperature 2nd month: R2: 0.65, p<0.001 3rd month: R2: 0.79, p<0.001 4th month: R2: 0.61, p<0.001
Vietnam [27]	Rainfall, temperature 1991-2001	Shigell-osis/ dysentery, typhoid, cholera	Correlation, collinearity analysis Stepwise multiple linear regression analysis.	*Stepwise regression* Shigellosis/ dysentery: 0.589 rainfall p<0.000, poverty. Typhoid fever: rainfall-temperature not in final model. Cholera: rainfall 0.417(p=0.003), public well drinking water.
Niger [22]	Rainfall 1996-2002	Menin-gococcal meningitis	Correlation	Negative association with rainfall R=-0.27, p=0.01
Burkina Faso, Niger,Mali, Togo [23]	Rainfall 1989-99	Menin-gococcal meningitis	Regression, adjusted for April aerosol index anomaly, October aerosol index anomaly	*August rainfall anomaly (-0.246, p<0.001* *January rainfall anomaly 0 or 1 (0.258, p<0.001)*
Sri Lanka [28]	Rainfall, temperature March 2000-June 2001 daily	Helminth infection	Correlation, Multiple regression, adjusted for total rainfall, number of wet days per month, mean temperature	*Correlation* Rainfall: no sign Temperature: -0.407 p=0.043 Wet-days: 0.564 p=0.003 Regression: rainfall, temperature no sign, wetdays: 1.155 p=0.008.
Argentina, Las Lomitas [29]	Rainfall 1992-1999	Leishman -iasis	Multiple regression Adjusted for average rainfall (May-june) Total precipitation previous yeasr	Regression: 0.028 average rainfall, significant. 0.01 previous year precipitation, significant.

Low rainfall or low humidity has been suggested to increase the risk of meningococcal meningitis (MCM) transmission. Two studies found a negative correlation between rainfall and MCM (22,23), even after adjustment for an aerosol index (23). Another study found an association between winter climate and MCM, through the enhanced Harmattan winds (after controlling for temperature) but the study did not a measure of effect. A study in Sri Lanka (28) found that the number of wet days in a month was positive related to helminth infection (after controlling for rainfall or temperature).

Overall, the limited number of studies for each health outcome/disease makes interpretation difficult as it is not possible to look for consistency between studies. Some weather-health relationships are likely to depend on the local context and it may not be wise to generalise from these studies.

Annual time series studies

We found only 5 studies that quantified the association between inter-annual climate variability and child health (see table 3).

Table 3. Annual time series studies of weather and child health.

Population, Area	Exposure	Health outcome	Methods	Results
Tanzania 2 locations: Morogoro and Kagera [47]	Monthly rainfall Temperature 10 years (including 1997 ENSO).	Low birthweight, primigrav-idae and multigrav-idae [hospital data]	Bivariate analysis.	*Kagera:* one period with a significant impact on birthweight difference (April-August 1998, in connection with ENSO), when the difference was 367g , a difference of 155g compared with the mean birthweight difference for the whole period. *Morogoro:* no effect
22 villages in Usambara Mountains in North-East Tanzania [48]	1997-1998 ENSO year Monthly rainfall Temperature	Malaria incidence	Wilcoxon's signed-rank test	High rainfall associated with ENSO event led to a general reduction in malaria.19.6% before ENSO vs 11.3% after ENSO, p=0.014.
Highland region, Uganda [49]	Monthly rainfall, Dec 1997 to April 1998	Malaria incidence (clinic al records)	Cross-correlation between monthly time series data	No association found.
Kabarole District, Uganda [50]	Rainfall 1995 to 1997	Malaria monthly incidence, 0-4 years	Spearmans rank correlation test	Correlation between rainfall and malaria incidence, 2-3 month lag, r=.43, p=0.008.
Rwanda [18]	1987 ENSO year	Malaria mortality	Mantel- Haenszel test for trend	The number of malaria cases rose sharply after the second half of 1987.The rise was greater in high altitude zone than middle or low. (501vs 323%, p<0.0005).

Many of these studies suggest linkages between local health effects and the climate phenomenon the El Niño-Southern Oscillation (ENSO). ENSO is an important determinant of inter-annual variability in many areas around the globe (30). None of the studies adjusted for confounders and all of them performed bivariate analysis.

A published review of ENSO and infectious disease studies (31) found good evidence the ENSO increases the risk of malaria in certain areas (South America) and also an effect on cholera transmission in coastal Bangladesh. That review was limited to papers that included more than one ENSO event. In this review, we included all papers that mentioned ENSO as a cause provided they also quantified the association with a meteorological parameter.

DISCUSSION

Child health in low and middle income countries is affected by climate and weather. The evidence for malaria is particularly strong, but other diseases have been less well studied. Of the 35 studies that we reviewed, 26 studies studied the association between rainfall and a child health outcome and 22 found a statistically significant association. The direction and intensity of this effect varied by disease and location. A positive association between rainfall and malaria (5,32) is consistent with knowledge about the impact of rainfall on mosquito vector populations. However, several studies found a negative effect of rainfall on child mortality (11,13,33) and the mechanisms for this association were not clear. Several studies highlighted that relationships between rainfall and health are non-linear or are mediated by agro-climatic conditions, but few studies properly modelled the non linearity of these effects (see below for modelling issues). Nineteen studies looked at the relationship between temperature and child health outcomes. The results reveal a consistent positive association between temperature and disease incidence or mortality. In other words, higher temperatures tend to increase disease risks over time or that disease distributions are limited by lower temperatures due to the behaviour of vector, pathogen or host species. The exception here was evidence of the effect of low temperatures on daily mortality in rural Bangladesh (24).

Few studies reported disease risk or survival data by age of the child to allow a separate assessment of the effect of climate/weather from infant to adulthood. However, those that did found that the effect on child health varied by age. Balk et al (33) that found that variation in daily rainfall has a greater impact on children aged 1-4 years than on infants. Children living in an area with less than 2ml of daily rainfall (average), had a probability of survival after 59 months of 86.5%, whereas children living in a areas with more than average daily rainfall had a 92% chance of surviving after age 12 months. Santos and Henry (11) found that the risk of death by place of residence varies only after the weaning period, confirming the protective effect of breastfeeding on child health (exposure to pathogens start with the introduction of complementary feeding).

Methodological issues

Overall, we found few studies were of high quality and made appropriate adjustment for confounders. Most diseases show seasonal patterns, but not all seasonal patterns are directly climate related (e.g. they could be due to behaviour). Seasonality should be taken into account in studies otherwise it may lead to spurious results. Adjustment for season is important for time series studies where the unit is daily, weekly or monthly outcome data. In the cross sectional studies (see table 1) only a few explicitly controlled for seasonality (11,13,33).

Amongst the time series studies, only the studies undertaken in Fiji and Bangladesh explicitly control for seasonality (9). Not adjusting for season is likely to over-estimate the effect of climate or weather factors.

The availability of health and environmental data at the appropriate spatial and temporal resolution was clearly a limitation for many studies. Many time series studies were conducted with only short data series leading to a lack of power. DHS /survey data were used in many cross-sectional studies but must be of comparable quality and the time of year in which the data were collected should be taken into account.

Only a few studies made a specific effort to establish whether the effect of rainfall or temperature was linear or non linear. For example, sensitivity analyses were used to explore the non-linear relationship between the weather variable and child health in the study in Burkina Faso (5). The effect of rainfall on malaria was non-linear with an approximate threshold of 100mm per month. The effect of humidity increased exponentially above values exceeding 60%. Rosenberg and Schultz (12) found that the effect of rainfall on child mortality in Colombia was characterised by a quadratic function. A non linear effect of rainfall on child survival was also found in the multi-country study of Balk et al (33). Daily time series studies have shown that the effect of temperature on all-cause mortality is typically non-linear, with an increased risk at both high and low temperatures.

Many of the longer term rainfall affects may be mediated by complex interactions between rainfall and local ecological or agricultural factors. For example, a study in Burkina Faso found that in periods of drought (<85% of average rainfall) children living in a region with level of precipitation above 900mm have lower risk of dying than children living in a "dryer" region (500mm-699mm of precipitation) (11). In the dryer region, the risk of child mortality is reduced (odd ration (OR): 0.63 $p<0.05$) after a year with more than 85% of the average rainfall. In the wetter region (900mm and over) the risk of mortality is higher (OR 1.89 P=0.10) when rainfall is more abundant (OR: 3.01 P= -0.05 for children 0-6 months).

Timing of exposures

The effect of temperature and rainfall on health events is often delayed. For example, heavy rainfall is known to increase the abundance of certain malaria vectors after a delay of about two weeks. The incubation time for the disease also needs to be considered (the time between infection and illness) (34). In a study in Burkina Faso (5), malaria incidence was related to the previous month's rainfall. In a time series study in Rwanda (18) temperature and rainfall act on malaria through lags of 1-2 and 2-3 months, respectively. In Tunisia (14), higher than average rainfall is associated with an increase in leishmaniasis in the following year (the hypothesis is that transmission in humans is modulated by the intensity of transmission in the canine reservoir in the previous year). A time series study in Fiji (9) found a positive association between temperature and diarrhoea when the temperature variable was lagged by one month; a 3% increase in diarrhoea per degree increase in temperature in the previous month after controlling for season. Low rainfall was associated with a statistically significant increase in diarrhoea in the same month and the following month.

A study in Senegal (13) found evidence of a link between the seasonality of conception (which may be partly explained by seasonal food availability and biological factors) and child mortality. Specifically the study found that above average rainfall in the 12 months prior to conception increased the probability of child survival.

Modelling survival or risk of infection by time of exposure

Few studies appropriately modelled the risk of infection or mortality by adjusting for confounders and exposure to specific weather patterns (11-13). Two studies acknowledged that the risk of mortality is dependent on fertility and jointly modelled the effects of weather on fertility and the effects of weather on mortality (12,13). This modelling choice (with respect to mortality) is the most appropriate as it is known that the season of birth is often a proxy for a seasonal/weather influences [35]. Hence, the failure to control for time of conception on mortality data may lead to over estimation of the effect of weather-related variable on child mortality.

Limitations of review

There were several limitations to this review. First, we were not able to access some non-English language papers. There was also likely to be a publication bias, as those studies that report a positive association are more likely to be published. As temperature, rainfall etc are not considered classic risk factors, it was very difficult to conduct a systematic search on these exposures. Many non-relevant studies were identified (particularly laboratory studies). Further, it was also difficult to identify studies for outcomes in children, and it is possible that we have missed some studies where children not clearly identified but accounted for a significant proportion of the outcome being studied. Some studies included both rural and urban areas, and we have included these where the rural results were reported.

Conclusions

There is good evidence that climate factors (temperature and rainfall) affect the spatial and temporal distribution of malaria in Africa, however there was limited evidence for other diseases. The review highlighted that little is known about the specific mechanism that link climate patterns and a range of diseases. Few analyses were of high quality, which would include adjustment for spatial or temporal confounders. Many studies did not distinguish between seasonal and other climate effects making interpretation difficult. There is a need for more research to describe the mechanisms by which climate variability affects child health and to identify those communities most at risk we need both improve the understanding of the epidemiology of disease and identify interventions to lower the impact of the changing climate.

This review specifically highlights the need of tailoring study design and data collection in order to properly establish the causal effect of climate or weather patterns on health outcomes. Cross sectional studies provide the depth of information on the characteristics of the population at risk allowing the adjustments of the estimate for confounders. Failure to properly distinguish seasonal from other effects is a common limitation of many of the published studies. As climate is a long term average, it important that exposure and outcome data cover a sufficiently long and sufficiently comparable time period.

Health planners are used to dealing with spatial risk concepts in order to plan disease control strategies, but there is still a lack of experience with temporal risk management (23,31). As seasonal forecasts are improving (which forecast the risk of anomalous rainfall 3 to 6 months ahead), they are likely to be included in health planning. Improved surveillance of diseases and health outcomes which appear to be influenced by climate factors will provide better quality data for research and enhance attempts to prevent adverse effects.

Climate change may increase poor people's vulnerability by adversely affecting their health directly. Information about current effects of the current climate on health (from cross sectional studies) provides important information about future vulnerability to climate change. However, many non-climate factors will also change in the coming decades and these must be considered in any climate change assessment. Information of the acute effects of weather (from time series studies) provides some information about vulnerability to weather extremes. Climate change will also act indirectly by adversely affecting livelihoods and undermining growth opportunities (36-38). There is a need for more research to describe the mechanisms by which climate variability affects child health and to identify those populations that are more vulnerable to changes in climate in the next few decades.

Many communities are highly dependent on natural resources and have a limited capacity to cope with climate variability. This is shown the relatively high impact of climate and weather on child health. Local perspectives and adaptive responses to climate change including collective action for natural resource management have been already proven to be successful strategies in some parts of the world (39-40). The problem of climate change is expected to be significant in Africa because vulnerability to climate variability is already high, current information is low, technological change has been the slowest and the domestic economies are heavily dependent of the agricultural sector (41).

Despite the limited evidence available it is clear that short-term changes in rainfall and temperature patterns have an impact on the health of children under the current climate. Children and pregnant women are particularly susceptible to vector and water-borne diseases, affecting the chances for developing countries to met the health related MDGs target (42). Child health will have indirect impacts on children's chances of access to education, with direct implications for future development opportunities for many developing countries. Recently a number of studies have shown that early childhood health influences the achievement of traits that are rewarded in the labour market such as improved cognitive performance, higher educational attainment, and positive personality attributes (43). In Sub-Saharan Africa, the lack of attention to this issue has been detrimental to the development of sound economic policy. Widespread poverty, high incidence of morbidity and mortality accompanied by a lack of investment in future generations is keeping African economies in a 'poverty trap'. The relative exposure to climate effects of "The Bottom Billion" (44), specifically the direct impact of a changing climate on their livelihood, coupled with low capacity to adapt, reinforce their development traps.

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Chapter 3

PROTECTING OUR HEALTH AND ENVIRONMENT

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Bioethics illuminates considerations that bear on health and healthcare. From a bioethical perspective this paper reviews some of the most credible medical literature on health impacts of climate change, highlights concerns regarding rural children, and provides perspective on public health responses and policy. Climate change has reciprocal and interconnected effects on humans and ecosystems. Global population growth increases energy use, landfill and toxic waste, and animal consumption with dynamic and interactive contributions to climate change, food insecurity, morbidity, and mortality. The most pronounced harms threaten not only health but child growth and development – with individual and societal costs. Rural populations are more directly exposed to their environments than others and have limited access to resources. Rural children may therefore have less opportunity to learn skills central to protecting their health, environment, and future. Immediate and concerted responses grounded in public health evidence can mitigate climate change and its health impacts. Public health contributions are essential in generating data, policy, and effective responses to climate-related concerns. Bioethics has a role in framing regional and global data on climate, disease, and risk factors in ways that engage social marketing and drive policy and behavior change. Public health and bioethics have central roles in framing public opinion and generating political will to reform policy and practices in healthcare, agriculture, and other sectors that contribute to climate change.

INTRODUCTION

It is increasingly clear that human activities are depleting earth's finite natural resources. Even wealthy nations experience health effects that result from climate change. Rural societies are especially vulnerable because of their exposure to and reliance on the environment. Energy use and agricultural practices that sustain the worlds growing population

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contribute significantly to climate change. Public health must begin to anticipate, assess, and document the complex, dynamic, and interrelated effects. It must convey the urgency of reducing greenhouse gas emissions (GHG) and identify strategic responses (1).

This chapter considers global health consequences of climate change with special attention to rural children and specifies roles that public health and bioethics may have in averting these. Rural children, particularly those in poor nations, are directly exposed to their physical environments. They have fewer resources and opportunities with which to learn skills central to protecting their health, environment, and future wellbeing.

Bioethics is concerned with differences (inequalities) and injustices (inequities) and how these impact on health. It supports human rights documents that specify the rights of children and others to healthy environments. Bioethics, however, pays relatively little attention to geographic or environmental differences that contribute to health like higher rates of serious illness in rural rather than urban areas, and malaria which primarily affects African children (2). Bioethics addresses morality, which is central to how public and political information is framed and incorporated into policy (3).

Direct connections between GHG and specific behaviors, business practices, and policies are sometimes unclear but these contribute to GHG and climate change. Directly or indirectly these worsen the severity of heat waves, floods, and severe storms in Europe; typhoons in Asia; drought from Africa to Australia; irreversibly melting polar ice caps, significant changes in global temperatures and sea levels; and the associated morbidity, mortality, and destruction. In 2009 the Philippines experienced 16 inches of rainfall in 12 hours far exceeding its previous records (4); Australia had a dust storm that closed Sydney's airport and generated hundreds of respiratory-related ambulance calls (5); and wind and drought in Iraq devastated the production of what was once 75% of the worlds dates (6). North America has increasingly frequent and severe public health and agricultural damage associated with extreme weather, drought, wildfires, floods, and water rationing.

Food security relies on agriculture which both contributes to, and is impacted by, GHG. Livestock production alone generates 20% of global GHG (1). By 2050 changes in temperature, rainfall, and seasonal pests will reduce wheat and rice yields in poor nations by 30% and 15% respectively; raise global prices for wheat, rice, and corn over 170%; and cause 25 million additional children to be malnourished - primarily in poor and rural areas (7). Effective responses require data regarding the complex feedback loops and long term impacts; education of culturally and geographically diverse communities; and engagement with industry and policy (1).

Lifestyles in wealthy nations pose a major challenge to mitigating climate change (8). Necessary behavior change requires information, incentives, and emphasis on the benefits of low-carbon living (8). Cost-effective means of reducing climate change exist so uncertainty about the full range of effects and interactions is no excuse for inaction (9). Bioethics should inform and promote debate about which public health and societal responses will be practical, efficient, and sustainable.

LITERATURE REVIEW

Bioethical methods emphasize reasoning in light of principles, theories, standards, moral duty, and contextual information.. Literature reviews are one means of obtaining evidence. Their validity relies on the integrity of the authors, reviewers, editors, and journals. This chapter reviews work published in highly regarded peer reviewed journals of public health, medicine, and bioethics. Relatively few publications address the health effects of climate change and fewer directly consider rural child health. The recent work reviewed here grounds discussion about public health and bioethics roles in mitigating health impacts of activities that contribute to, and are impacted by, climate change.

What we found

Health effects

The health impacts of climate change are interconnected, heterogeneous, and reciprocal (1). As global population rises more landfill and other waste accumulates. In rural areas where resources for management are limited waste is often burned and causes smoke-related problems including persistent rash, eye irritation, cough, headache, fever, and vomiting among nearby residents. Although landfill waste generates large amounts of methane and leaches chemicals into the environment few policies to minimize it exist.

Modifiable human activities contribute to climate-related air pollution, waterborne pathogens that kill millions of children annually (10), and altered patterns of infectious disease (8). As temperatures rise vectors carry pathogens into new locations. Meningitis has appeared in West Africa, tick borne encephalitis in Sweden, cholera in Venezuela and Bangladesh, malaria and dengue fever affect wider regions, and several nations report increased incidence of Salmonella (11). Most livestock feed contains low levels of antibiotics which facilitate drug resistant bacteria and can contribute to human infection (12).

Climate change reduces agricultural productivity and threatens food security while increasing poverty and mortality (13). Populations most at risk are those in coastal, mountainous, or polar regions (14) exposed to and reliant on the natural environment. Rural children are particularly vulnerable because in addition to direct impacts like malnutrition or vector-borne disease their long term growth rates and cognitive development are impaired. Individual and societal causes, costs, and long-term outcomes attest to the complex reciprocal interactions associated with GHG.

Rural children and women are perhaps most vulnerable to environmental changes given their greater reliance on the environment and limited educational, occupational, and healthcare choices. When food is scarce, cassava processing (primarily by women in poorly ventilated sheds with children underfoot) is hurried and releases hydrogen cyanide which causes paralysis (15). Pesticide exposure corresponds with complications of pregnancy including fetal malformation among rural floriculture workers in Columbia (15). Rural adolescents in Poland have higher rates of serious accidents, chemical poisoning, and poor physical and educational development – particularly females (16). Rural children in the U.S. have elevated risk of cancer possibly due to long-term low-level pesticide exposure (17).

When confronted by scarcity of food, water, fuel, or conflict rural people may migrate to cities but may remain unemployed, turn to drug or alcohol abuse, crime, or sex work through which they contract and spread sexually transmitted diseases and HIV (10). Sex work exposes women and their children to risks of physical and mental abuse endangering health and child development. Economic and social development projects should recognize that climate-sensitive conditions like malaria, diarrhea, and undernutrition primarily affect children and that "protecting the environment and providing for the health, education, and development of children are mutually inclusive goals" (18).

Instability of food and water is a growing global problem. Rivers in Kenya's Mau forest provide water to ten million people, six lakes, and eight major wildlife preserves but agricultural practices of recent decades cause potentially irreversible environmental damage, contribute to drought that kills thousands of livestock and wildlife, and generate civil conflict (19). By 2020 crop yields will fall 30-50% in parts of Africa and Asia due to shrinking glaciers and the resultant diminished irrigation (20). Extreme weather, pest infestations, and sea-level rises will further reduce these yields but GHG per unit animal produced can be reduced at low cost while improving soil and water, and protecting against pathogens (20).

By 2050 global livestock production will double to 465 million tons of meat and over 1000 million tons of milk (20). In China meat consumption has doubled over ten years as has chicken and pork production. Formerly a net exporter of soybeans China increasingly imports soybean feed as do India, South Africa, and the EU (20). Livestock production uses over 30% of global land surface for grazing and feed crops generating deforestation, releasing gas from animals and fertilizers, and using energy for irrigation, processing, and transporting feed and meat (20).

Possible responses

A traditional rural diet based largely on vegetable products with small quantities of animal foods is associated with lower rates of diabetes, hypertension, and coronary heart disease in rural parts of India, Mexico, Brazil, and Chile (20). Redirecting grain to human consumption and reducing state subsidies for animal feed would have global health benefits and reduce GHG (20). The "contraction and convergence" model aims to reduce animal consumption in wealthy nations, taper rising consumption in developing countries, and improve health globally as GHG declines (20).

Modernizing agricultural practices in low and middle income nations could also reduce GHG while improving soil capacity, increasing food yields, and reversing land degradation (9). For example, switching from biomass to modern fuels directly benefits women and children who live or work near the smoke. Providing a simple diesel powered platform to women in Mali for grinding grain, pressing vegetable oil, and pumping water reduced their chores by two hours daily and increased their agricultural income by 32% daily; similar outcomes accrued in Kenya (9).

Today's global population growth is not sustainable given that overall energy used to produce food greatly exceeds food energy yield (20). In 2002 global population rose by over 200,000 each minute and grew from 5 to 6 billion in only 12 years; from under 7 billion today it will rise to over 9 billion by 2050 (21). Zero population growth was promoted internationally in the 1960's to protect the environment but efforts to elevate birth rates in wealthy nations currently dominate (22). Improving access to contraceptive knowledge and methods would reduce population growth and help achieve the Millennium Development

Goals (20). The most cost-effective measure to mitigate climate change could be providing condoms and simple birth-control methods to those wishing to limit their own family size (9) with direct health benefits for women and children.

DISCUSSION

Bioethical analysis

Bioethics functions to outline uncertainties, implications, abuses, and perspectives (23). It is integral to policymaking (24), can explore the moral foundations for climate policy (25), and illuminate challenges therein which include "vested interests, political inertia, wide global inequalities, weak technology-transfer mechanisms, and gaps in knowledge" (9). Bioethics is helpful in identifying self interests that take many forms and that may obscure attention and objectivity (23). Even meteorologists seemingly ignore links between catastrophic weather and human contributions to GHG.

Climate change may seem amorphous or futuristic and many mistakenly believe that their personal contributions are insignificant (26). Health officials in the U.S. recognize the threat but few believe their departments are prepared to respond (27). Objectively framing and publicizing the issues for research, debate, and responses could help overcome inertia, uncertainty, and self interests that compromise mitigation responses. Objective analysis is central to bioethics and might demonstrate the level of urgency warranted in responding to climate change.

In public health "the precautionary principle stipulates an obligation to protect populations against reasonably foreseeable threats, even under conditions of uncertainty … Given the potential costs of inaction" failure to implement preventive measures requires justification (28). Public health, bioethics and other disciplines should shift attention from the interests of a select few to the grave health threats of GHG. Emphasis on the need to protect innocent victims, particularly children, spurred tobacco control policies in the U.S. (28) and might do the same for climate policies.

Ways forward

Children may be the greatest victims of climate change but are also potential protagonists who should be helped to understand and think critically about their local environment, and to eradicate risks and live harmoniously with nature (18). Homes, schools, and health centers in rural areas offer opportunities to improve energy efficiency and conservation (18). Development projects must be tailored to age, gender, and other factors, and children must have access to mental health support after disasters (29).

Information about specific problems, injustices, and the need for change can drive public opinion and policy, especially if leaders champion the issues and mobilize action (3). Public health should study the costs and benefits of interventions, refine means of collecting and sharing data, and broaden collaborations (29). It can provide region specific data on disease, risk factors, and social marketing outcomes. Marketers should help create and distribute target-specific messages. Brochures on conservation left in waiting rooms and clinics, for example, impact both workforce and patients (30).

Policies to increase shade trees and bicycle paths reduce traffic, road injury, noise, obesity, diabetes, and cardiovascular disease while saving money and beautifying the environment (9). That obesity rates are low in Sweden and elderly are visible and vigorous may correspond with policies that encourage walking, biking, and wholesome foods. Conservation policies in Germany contributed to technological advances that increased its capacity to accept and dispose of excess landfill waste from other nations.

Health institutions generate tons of waste and use enormous amounts of energy but policies could cost-effectively reduce their contributions (25). Industrial nations have a responsibility to decrease GHG and cost-effective means of doing so exist (31). Research is needed on how best to monitor health impacts, reduce food processing and transportation, promote policies to reduce waste and conserve resources, and ensure public understanding (29).

Individual conservation measures help over time like driving less, switching off computers and appliances when not in use, consuming fewer animal products, purchasing less packaged and more local and organic products. Returning to the “waste not, want not” mentality of previous generations would reduce consumption and energy use. Plastic bottles of soap have become the norm in wealthy nations but are no more hygienic or inexpensive to purchase than minimally packaged bars of soap. Countless similar examples exist. How often are new toiletries, clothes, cell phones, or cars needed? How many square feet to heat or cool are necessary in a new house?

Bioethics should draw attention to and help elucidate the many interconnected concerns regarding climate change and health. These will often include competing interests between economic development and long term environmental health impacts. Bioethical methods are often used to weigh competing interests and balance issues of justice. Justice links bioethics with human rights. Climate change threatens human rights, particularly those of vulnerable groups including children and rural communities. Bioethics should begin to address the health threats of climate change from the perspective of rights and justice, and to contribute understanding regarding the utility of social and economic development projects genereated by corporate and other realms.

Solutions to climate change require political will and coordinated efforts at the global level (9). Bioethics perspectives have much to offer in objectivity and educating the public about threats of GHG and means of minimizing GHG. Within the realm of public health bioethics should help to inform and evaluate policy and priorities to reduce GHG and protect health. Governments, societies, and businesses must protect the innocent and vulnerable, including children, from foreseeable impacts. Public health and bioethics have unique knowledge, leverage, and resources with which to respond. Their collective and individual efforts can provide valuable evidence and teach constructive responses that mitigate health effects (26).

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Chapter 4

IMPACT OF GLOBAL CLIMATE CHANGE ON CHILDREN'S HEALTH AND WELL-BEING

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It is virtually certain that global climate change and its impact on the health and well-being of children will intensify. Human rights and equity-based analyses of the effects of climate change provide a unique and strategic approach to understand its complexities and to respond. The UN Convention on the Rights of the Child (UNCRC) provides a framework for this inquiry. In this chapter we present a collection of rights and equity-based tools that can be used to analyze and address the current and projected impact of climate change on children's health and well-being. An ontological process was used to categorize and link the articles of the UNCRC to factors related to the pathways, outcomes, ethics and impact of climate change on children. UNCRC articles are categorized into five matrices that relate the impact of climate change to: a) economic, cultural, social, protective and civil-political rights, b) protection, provision and participation rights, c) pathways and outcomes of climate change and related rights, d) prevention, intervention and mitigation strategies related to children's physical, behavioral and social health and relevant child health needs and rights, and e) UNCRC articles and ethics principles. The principles of children's rights provide the tools required to understand and respond to the effects of climate change on the health and well-being of children. The UNCRC is a universally accepted framework to support these efforts. It is through the fulfillment of children's rights that child health equity can be achieved in the face of global climate change.

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INTRODUCTION

Global climate change is the single most important contemporary human rights issue confronting children and youth. As such, a rights and equity-based analysis of the impact of climate change on children provides a unique and strategic approach to understand the complexity of the challenges it poses, and to structure a response. The United Nations Convention on the Rights of the Child (UNCRC) establishes a context and framework for this inquiry (1). In one holistic document, the UNCRC defines the prerequisites for the health and well-being of all children. By framing the current and projected impact of climate change as violations of children's rights, and relating each of these violations to specific articles of the UNCRC, a comprehensive inventory of the potential adverse effects of climate change on children can be generated. Once defined, the principles of child rights and health equity provide a foundation, blueprint and tools with which to structure a response.

Vulnerabilities of children to climate change

Children are among the populations most vulnerable to the biological, as well social and environmental, impact of climate change (2-7). This is particularly true for children in developing countries where nearly 85 percent of children and youth live. More than 2.2 billion people are under the age of 18; more than 1.2 billion are 9 years of age or younger.

Due to their physical, cognitive and behavioral immaturity, children are more susceptible to the adverse effects of environmental degradation than adults; (2-7,8-10) and their developmental trajectory requires a longitudinal consideration of climate change's adverse effects. An insult early in life may affect an individual's health throughout his or her life course (9,11). This has implications for assessing the current and projected impact of climate change on children and the adults they will become, the generation of life course-indicators and the evaluation of policies and programs that operate at the three levels of response—prevention, intervention and mitigation. The longitudinal impact of this tri-level response on the physical, behavioral and social health and well-being of children must be considered in the assessment and prioritization of any actions related to climate change. To maximize and sustain their effectiveness, all responses must engage children as active participants (6).

Children are particularly vulnerable to the impact of climate change on the political, social, economic and cultural milieus in which they grow and develop. Each of these domains is inter-related through complex interactions that magnify their adverse effects (see figure 1). These complexities will be mediated through physical injuries (floods, storms, fires); environmentally acquired conditions (heat stroke, hypothermia, cardio-respiratory diseases, asthma); vector-borne communicable diseases (malaria, dengue, schistosomiasis); food and water-borne diseases; and malnutrition related disorders, including stunted growth and development due to food scarcities resulting from drought and other agricultural stresses (12). The combination of these effects with the physical, mental, cognitive and developmental changes occurring in children amplifies the potential immediate and long-term impact of climate change.

Figure 1. Child rights foundations and child health and well-being.

Vignettes of a changing world

These adverse effects are not theoretical, as much evidence has already been accrued linking the impact of environmental change to children's health. More than a third of deaths in children younger than 14 years is attributable to illness and conditions related to poor environments (13). Climate change is expected to increase the burden of diarrheal disease alone in low-income regions by 5 percent by 2020 (12). By 2030, the number of people suffering hunger and illness due to incremental changes in climate, such as shifting rainfall and drought patterns, could reach more than 300 million, with nearly half a million deaths annually (14).

The effects of global climate change will occur along a spectrum from large-scale, sudden-onset disasters that result in injuries, under-nutrition or disease to gradual ecosystem changes that lead to sustained deteriorating environmental conditions. Each will exacerbate existing adverse conditions that already challenge the marginalized existence of children in both the developed and developing world. Climate change is expected to intensify these combined threats to children and is also likely to accelerate certain large-scale environmental changes, including desertification, diminishing freshwater resources and biodiversity loss, which will have far-reaching effects on child health and well-being (2-7). By 2050, climate change may force 200 million men, women and children to migrate (15).

This manuscript will present several rights-based tools that can be used to analyze and shape the response to the current and potential impact of climate change on the health and well-being of children. An in-depth analysis and presentation of the use of these tools is beyond the scope of this manuscript. As children represent nearly one third of the world's population and 100 percent of our future—preventing, intervening and mitigating the adverse effects of climate change on children must be a global priority. It is only by fulfilling the rights of children that child health equity can be achieved in the face of global climate change.

UNCRC

The UNCRC consists of 54 articles that define a holistic set of rights due to children (Articles 1 to 41) and others that define what is required of countries to adhere to it (Articles 42 to 45) (1). For the purpose of transforming the UNCRC into a set of tools for analyzing and addressing the current and projected impact of climate change on children, a collection of ontologies (see tables 1-5) that relate its effects to an array of factors, including the articles of the UNCRC, is presented. Each of the tools can be used individually or in combination. When used sequentially, they present a logical, coherent and comprehensive assessment of climate change that can be employed to educate the public and decision makers; structure prevention, intervention and mitigation responses; and for research and program evaluation.

For the purposes of this manuscript, the definition of human (child) rights and health equity are as follow:

- Human rights. The "basic rights and freedoms to which all humans are entitled." Human rights provide a useful framework for shaping national laws and policies, a tool for ensuring accountability and an approach to promoting public health (16).
- Health equity. Systematic differences in health that are judged to be avoidable by reasonable action (17).

It is important to note that both definitions express an orientation to action—the consideration of "rights" and "equity" as not only outcomes, but also as tools to affect these outcomes. They reflect the dynamic nature of an approach to climate change that uses rights and equity as both a foundation to support action, and as a set of tools to prevent, intervene and mitigate its effects on children.

IMPACT

Current models for the impact of climate change on child health and well-being focus primarily on direct biomedical mechanisms, e.g., injury, vector-borne communicable and diarrheal diseases, heat stroke, etc.; and limit consideration of the broader and often more proximal impact of climate change on the socioeconomic, political and cultural determinants that affect children and childhood. These are the determinants that will most often lead to the biological effects of climate change. Table 1 categorizes these determinants in relation to the articles of the UNCRC and the projected impact of climate change (1,3). This matrix can be used as a tool to assess and ensure the breadth of the potential effects of climate change on children is considered in any analyses or decisions.

Table 1. Summary of key economic, cultural, social, protective and civil-political, articles of the UN Convention on the rights of the child in relation to the impact of climate change.

Domain	UNCRC Articles[1]	Climate Change Impact[3]
Economic	Article 27. Adequate standard of living Article 26. Social security Article 32. Protection from economic exploitation	Child poverty increases Loss of assets and livelihoods Decline in food security and income Agricultural yield changes
Cultural	Article 30. Respect for language, culture and religion Article 8. Identity	Ecosystem change Habitat change
Social	Article 6. Life, survival and development Article 24. Best possible health and access to health care Article 28. Education Article 31. Play Article 20. Family life or alternative care Article 10. Family reunification Article 23. Social inclusion for disabled children Article 18. Support for parents to ensure protection of children's rights	Child morbidity and mortality increases Child malnutrition increases More children out of school Mortality from sudden onset disasters, from non-communicable causes increases Communicable disease patterns extend and change
Protective	Article 3. Promotion of a child's best interests Article 32. Protection from abuse and exploitation Article 38. Protection from armed conflict Article 33. Protection from harmful drugs Article 35. Protection from trafficking Article 39. Rehabilitative care post abuse/neglect	Reduction of child protection Increase resource conflict Water stress Flooding Incidence of extreme events increases
Civil and Political	Article 12. Heard and taken seriously Article 2. Freedom from discrimination in the exercise of rights Article 15. Freedom of religion, association and expression Article 17. Privacy and information Article 37. Freedom from all forms of violence, torture or cruel and inhumane treatment Article 40. Recognition of the importance of treating the child with respect within the justice system, not to be detained arbitrarily and due process	Child equality decreases Forced population movement andmigration More frequent and severe drought More intense rainfall

Table 2. Summary of key protection, provision and participation articles of the UN Convention on the rights of the child in relation to the impact of climate change

Domains	UNCRC Articles[1]	Climate Change Impact[3]
Articles: Rights of Protection Articles: Rights of Provision Articles: Rights of Participation	Article 6. Right to life Article 9. Right not to be separated from parents Article 19. Right to be protected from all forms of abuse Article 20. Right to special attention if deprived of family Article 32. Right to protection from economic exploitation Article 33. Right to protection from Illicit drugs Article 34. Right to protection from sexual exploitation Article 24. Right to the highest standard of healthcare Article 27. Right to an adequate standard of living Article 28. Education Article 31. Play Article 20. Family life or alternative care Article 10. Family reunification Article 23. Social inclusion for disabled children Article 18. Support for parents to ensure protection of children's rights Article 7. Right to an identity Article 12. Right to a voice and to be listened to Article 17. Right to access to information Article 23. Right for disabled children to enjoy life and participate actively in society	Reduction of child protection Increase resource conflict Water stress Flooding Incidence of extreme events increases Child poverty increases Loss of assets and livelihoods Decline in food security and income Agricultural yield changes Child morbidity and mortality increases Child malnutrition increases More children out of school Mortality from sudden onset disasters, from non-communicable causes increases Communicable disease patterns extend and change More frequent and severe drought More intense rainfall Child equality decreases Forced population movement and migration

Table 2 divides the articles of the UNCRC into rights of Protection, Provision and Participation. This ontology of rights in relation to the impact of climate change provides a tool for structuring and facilitating a response to the current and potential effects of climate change on the needs and rights of children.

For example, by completing the following statements, decision makers can structure a strategic approach to address the impact of climate change on children.

- In order to protect the right of children to be free from economic exploitation (article 32) (1), resulting from the forced migration of families secondary to climate change, we will need to ________________.
- In order to provide for the rights of children to the highest standard of healthcare (article 24), (1) in environments in which resources are destroyed by natural disasters and/or economic collapse, we will need to ____________ .
- In order to ensure the participation of children in society with respect to their rights to an identity (articles 7 and 8) (1), that may be compromised by the loss of their parents or forced migration, we will need to______________.

Table 3 provides a tool to dissect and present the relationship between the pathways and consequent outcomes of climate change and specific UNCRC articles. Using the algorithm from UNICEF's publication Our climate, our children, our responsibility as an example (see figure 2) (3), the impact of climate change on children can be categorized into six domains, each of which is mediated through multiple pathways. Table 3 links these outcomes and pathways to the rights of children as delineated by specific articles in the UNCRC. This linkage of rights to the adverse effects of climate change provides a template for a classification system that can facilitate: a) impact analyses; b) the generation of rights and equity-based indicators; c) strategic approaches to prevention, intervention and mitigation; and d) global dialog, discussion and collaboration.

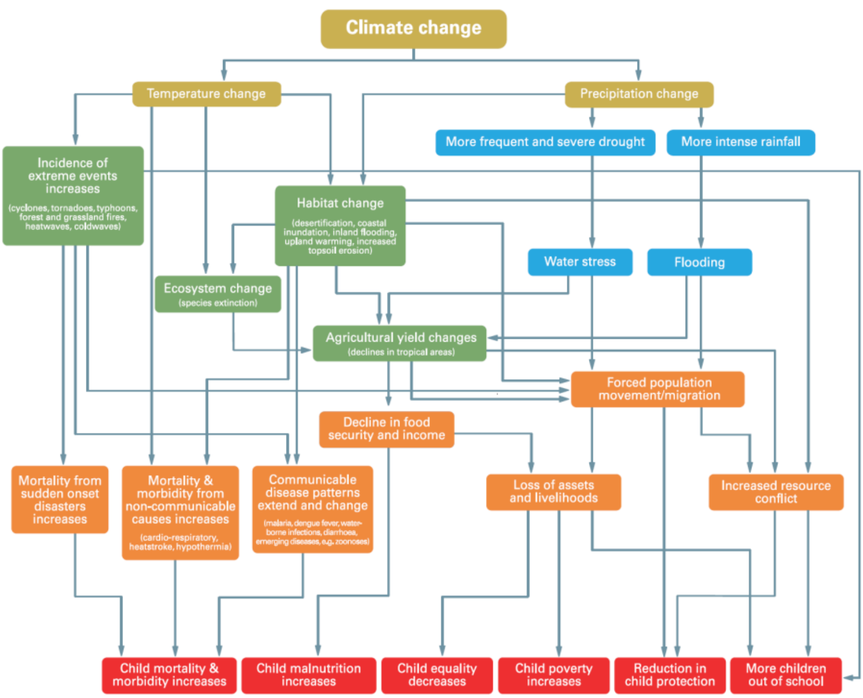

Figure 2. Climate change impact on child health.

Table 3. Impact of climate change on children: Outcomes, pathways and rights.

Outcomes[3]	Pathways[3]	UNCRC Articles[1]
Child mortality and morbidity increases / Child malnutrition increases	Disasters Non-communicable conditions (cardio-respiratory, heat stroke, hypothermia) Communicable diseases Decline in food security and income	6. Life, survival and development 24. Best possible health and access to health care 23. Rehabilitative care post abuse or neglect 27. Adequate standard of living
Child poverty increases		27. Adequate standard of living 26. Social security 32. Protection from economic exploitation
Child equality decreases	Forced migration Loss of assets and livelihoods	2. Non discrimination 20. Family life or alternative care 23. Fullest social inclusion for disabled children 18. Support for parents to ensure protection of children's rights
	Forced migration Loss of assets and livelihoods	7. Birth registration 8. Identity 12. Heard and taken seriously 17. Access to information 13. Freedom of expression 14. Freedom of religion 15. Freedom of association
Reduction in child protection	Forced population movement and migration Increased resource conflict	39. Physical and psychological recovery and social reintegration 3. Promotion of a child's best interests 9. Protection from separation from parents 10. Family reunification 11. Illicit adoption practices 16. Privacy 19. Protection from abuse and violence 20. Alternative care 22. Refugee status 38. Protection from armed conflict 33. Protection from harmful drugs 34. Sexual exploitation 35. Protection from trafficking 37. Freedom from all forms of violence, torture or other cruel and inhumane or degrading treatment 40. Due process in the law and treatment with respect within the justice system
More children out of school	Loss of assets and livelihoods Increased resource conflict Increase in extreme events	22. Humanitarian assistance 28. Education 30. Respect for language, culture and religion 31. Play

It is virtually certain that global climate change and its impact on children will continue to intensify (18,19). A tri-level response of prevention, intervention and mitigation will be required to: a) prevent future changes in climate and/or their adverse effects on children; b) intervene in the progression of climate change and "treat" the effects that have already occurred; and c) mitigate current and ongoing environmental and health effects. Table 4 presents a matrix that relates this tri-level response to the physical, behavioral and social health and well-being of children. The matrix can be used to structure the assessment of children's "needs" and "rights" that relate to each of the response domains as a prerequisite for considering the tasks required to address the impact of climate change on children.

Table 4. Tri-level response to climate change.

	Physical Health Needs Rights Tasks	Behavioral Health Needs Rights Tasks	Social Well-Being Needs Rights Tasks
Prevention			
Intervention			
Mitigation			

Finally, Table 5 presents the articles of the UNCRC arranged as economic, cultural, social, protective and civil-political rights (see table 1); and links them to the four basic ethical principles of autonomy, justice, beneficence and non-maleficence and the pathways and outcomes associated with climate change (see table 3). This matrix can be used to provide depth to our understanding and dialog concerning the longitudinal effects of climate change on children and adults, expand the indicators available for assessment and monitoring, and engage a range of professionals, e.g., ethicists and philosophers, who otherwise might not be involved in the discussion and response to climate change.

Table 5. Rights, ethics and the impact of climate change.

Taxonomy of Rights	Inventory of Rights[1]	Ethics Principles	Child Health Issues Associated with Climate Change[3]
Economic	Adequate standard of living Social security Protection from economic exploitation	Justice: Distributive and Allocative	Child poverty increases Loss of assets and livelihoods Decline in food security and income Agricultural yield changes
Cultural	Respect for language, culture and religion Abolition of traditional practices likely to be prejudicial to a child's health	Autonomy	Ecosystem change Habitat change
Social	Life, survival and development Best possible health and access to health care Education Play Family life or alternative care Family reunification Fullest social inclusion for disabled children Support for parents to ensure protection of children's rights	Beneficence	Child morbidity and mortality increases Child malnutrition increases More children out of school Mortality from sudden onset disasters, from non-communicable causes increases Communicable disease patterns extend and change

Table 5. (Continued).

Protective	Promotion of a child's best interests Protection from abuse and exploitation Protection from armed conflict Protection from harmful drugs Protection from trafficking Rehabilitative care post abuse or neglect	Non-maleficence	Reduction of child protection Increase resource conflict Water stress Flooding Incidence of extreme events increases
Civil and Political	Heard and taken seriously Freedom from discrimination in the exercise of rights Freedom of religion, association and expression Privacy and Information Respect for physical and personal integrity Freedom from all forms of violence, torture or other cruel and inhumane or degrading treatment Due process in the law Recognition of the importance of treating the child with respect within the justice system Not to be detained arbitrarily	Autonomy	Child equality decreases Forced population movement and migration More frequent and severe drought More intense rainfall

DISCUSSION

The principles of children's rights and equity provide a blueprint, foundation, framework and tools required to understand and respond to the current and projected effects of global climate change on the health and well-being of children and youth. The relevance and importance of a rights and equity-based approach to climate change cannot be overstated, as it facilitates a comprehensive assessment and response to these issues not offered by any other approach. The ontological tools presented in this manuscript will help to enable professionals and decision makers to address the core and essential functions of public health practice in relation to climate change (20).

As each of the articles of the UNCRC relates to a particular "need" of children for optimal survival and development (Article 6) (1), the UNCRC provides a means to consider the best interests of the child in all decisions related to climate change (Article 3) (1). It also provides a lexicon to translate the parlance of rights into a vernacular of children's "needs"—needs that will be negatively impacted by the effects of climate change. Use of this vernacular, framed in the context of Economic, Cultural, Social, Protective and Civil-Political rights, and Provision, Protection and Promotion rights/needs (see tables 1 and 2), will enable policy makers, civil society, scientists and other stakeholders to project the potential needs of children resulting from global climate change and organize, prioritize and legitimize their actions to prevent, intervene and mitigate its effects.

Climate change will challenge and potentially disrupt the role and capacity of states to assure, protect and fulfill children's rights. Although environmental change will impact both rich and poor people within countries, the principle tension is between rich industrialized countries (North) and less developed countries (South) in terms of environmental damage. In order to realize the rights of children in the shadow of climate change, it is critically important that an international dialog is initiated to determine how states will undertake "appropriate legislative, administrative and other measures" to ensure this outcome (Article 4) (1).

Given the magnitude of the potential adverse effects of climate change on children and families (21), and the special vulnerabilities of those living in developing countries (19,22,23), any and all responses will require international co-operation. Individual states will need to consider how they will make the principles and provisions of children's rights known to adults and children in the special circumstances presented by climate change (Article 42) (1), and the Committee on the Rights of the Child should require an analysis in states' reports (Article 44) (1). These analyses should include a discussion of how states will respect and support the capacities of nuclear and extended families to provide direction and guidance to children's exercise of their rights (Article 5) when confronted with the impact of climate change (1). Any discussion concerning the Millennium Development Goals must consider them in relation to how children will be affected by climate change (24). It is vitally important that UNICEF and the Committee on the Rights of the Child continue to solicit all available expertise on the potential effect of climate change on children, and recommend to the United Nations General Assembly to undertake ongoing studies in this regard (Article 45) (1).

In order to ensure a child's right to optimal survival and development (Article 6), all children without discrimination must be treated as bearers of all rights delineated in the UNCRC—there is no hierarchy of rights (Article 2) (1). An ontological approach to categorize, but not prioritize, the rights contained in the UNCRC provides a powerful and dynamic methodology to develop the tools required to structure a comprehensive rights-respecting and equity-based response to the issues children confront with respect to global climate change. This ontological methodology is also applicable to the spectrum of issues that affect the health and well-being of children.

Other rights and equity-based tools and strategies will be required to augment the use of the tools presented in this manuscript (see table 6). As experience with the development and use of these rights and equity-based tools is accrued, their relevance to program, community and policy advocacy; rights and equity-based indicators; and evaluation and research in relation to the impact of global climate change on children's health and well-being will become better defined. This experience will help to inform the dialog about intergenerational justice—that is, who and how are we going to pay the costs of damaging the environment for the coming generations?

Climate change now threatens to drive an even larger gap between industrialized and poor countries than currently exists. This reality and the complexity of the social, economic, political and cultural determinants of a child's well-being; the inexorable march toward globalization and the intricate intersection of the lives of children throughout the world dictate the need to establish a consistent and congruent international approach to the prevention, intervention and mitigation of the effects of climate change on children. The UNCRC provides a universally accepted framework to support these efforts and the tools required to advance equity among the world's children and youth.

Table 6. Examples of rights and equity-based tools.

Root cause analysis	Child Friendly Hospitals
Health Impact Assessment	Baby Friendly Hospitals
Environmental Impact Assessment	Medical-Legal Collaboration
Budget analysis	Gender Tools
Human Rights Documents	Cultural Competence
Media/Arts—Photo Voice	Children's Participation
Environmental Justice	Evidence-based Public Policy
Health Related Quality of Life	Intergenerational Justice
Equity-based Indicators	Community-based Participatory Research
Ombudsperson	Early Childhood Education
Child Friendly Cities	Children's Allowance

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Chapter 5

CLIMATE CHANGE AND CHILD HEALTH IN AUSTRALIA

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This century, Australians are likely to face higher temperatures, shifting rainfall systems, severe droughts and more fires and storms. Food and water costs are increasing, while weather-related disasters and droughts will generate financial insecurity, social dislocation and loss of livelihoods in affected farming, peri-urban and regional communities. These climate-induced changes are also likely to affect human health and well-being, especially children's. Because of their immature organ systems, neurobiology and dependence on caregivers, children are likely to be affected by heat stress, gastroenteritis and natural disasters, as well as family stresses linked to droughts, loss of livelihood and familial dislocation. Furthermore, because of climate change, children living today may confront even greater health risks over their lifetime, with available estimates indicating a 30-100% increase across selected health risks by 2050. Future generations may face a 3 to 15-fold increase by 2100 and we argue that they can be viewed as a form of health inequity. Indeed climate change suggests that two types of health inequities are likely. The first will be to lower the level of population health across current and future generations (including the generation of a health gap between today's adults and children living now). The second will be to increase the social gradient in health, with those with more resources better able to protect themselves from impacts and to adapt. An intergenerational framework helps clarify the human health impacts of climate change, and may help research and policy efforts to address the time lag between cause and health consequence.

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INTRODUCTION

> ”We are worried, but there is hope because we are a generation that knows more about these issues—we have more awareness and are more willing to make a change…..”
>
> Australian schoolchild on climate change, Voices of the Future (1)

Despite climatic vulnerability, few Australian policies on climate change and its health impacts have a child or intergenerational focus. Most research, policy and interventions assume a single generational focus; however the time lag from cause to consequence makes climate change an intergenerational issue, especially in terms of health and well being. This paper explores the relationship between intergenerational health inequities linked to climate change, focusing on children in Australia.

CLIMATE CHANGE: AUSTRALIA IN THE FRONTLINE

Australia is the most arid populated continent, and is therefore vulnerable to changes in temperature and rainfall on top of predicted southwards shifts in rainfall systems—many of them critical to regional farming practices. The key risks to the nation centre on extreme weather events, including cyclones, fires, higher temperatures, droughts and drying, with different regions likely to experience different impacts. In the north, a downward shift in rainfall systems increases risk of cyclones and storms in the populous areas of south-east Queensland and north-east New South Wales. Average temperatures in Australia have already increased by about 0.9^0C since 1910 (2), but much larger increases in the interior and northern areas are expected this century (3). South-eastern Australia expects an estimated 143% increase in catastrophic bushfires by 2050 (4) and the 2009 fires in south-east Victoria were unprecedented. Extended drought and high temperatures contributed to a series of fires that overwhelmed the state’s fire-fighting resources, leaving 173 people dead and at least 414 injured (5).

The most important impacts on the southern Australian landscape are long-term drying and droughts, with likely reductions in rainfall of around 10% (6). Relative to the period from 1974 to 2003, up to 20% more droughts are predicted over most of Australia by 2030, and up to 80% more in south-western Australia by 2070. Agricultural industries are also likely to be affected. The Murray Darling Basin river system supplies 70% of the water needed for the nation’s irrigated crops and pastures. Over 95% of the river system already shows evidence of environmental degradation. Climate change is forecast to further reduce annual stream flow by 10-25% in 2050 and 16-48% by 2100 (7). Financial hardship and dislocation are being reported in rural communities (8) and in cities, most residents are paying higher prices for, and face restrictions on, water. For example, Melbourne’s water storage is now about one half of the volume stored 10 years ago (9).

Thus, despite the nation’s affluence and political stability, the agricultural, economic and social costs from climate change could be significant. Climate change, and its interplay with economic and social systems, is also likely to affect human health and well-being and exacerbate existing health inequities (10).

HEALTH IMPACT IN AUSTRALIA FROM CLIMATE CHANGE

Climate change may not lead to new diseases and health disorders but instead alter the incidence, range and seasonality of existing ones (11). These health risks may be direct (via changes in the environment or ecosystem) or indirect (via climate-induced changes in economic or social systems).

Table 1. Summary of estimated direct health impacts from climate change, Australia 2050 and 2100.

Expected climate change	Vulnerable areas	Health impacts	Estimated health impacts 2050	Estimated health impacts 2100
More heat waves	Widespread, urban (heat island)	Deaths, hospitalisations	+36% deaths, + 186% hospitalisations(29)*	+195% deaths, + 223% hospitalisations (29)*
Increased average temperatures	Widespread (airborne allergens), urban (pollution)	Asthma, food poisoning (bacterial gastroenteritis including Salmonella)	Bacterial gastroenteritis + 334, 598 notifications annually[2] +11% indigenous child hospitalizations (12) ‡ ‡	Bacterial gastroenteritis + 870,198 notifications(29)**
Vector habitat change	Wider vector habitats 200km south and west	Dengue Fever, Ross River Virus	+114% people exposed dengue(29)***	+1500% people exposed dengue(29)***
More extreme weather disasters, fires, cyclones, flooding	Peri-urban, rural, coastal fringe (including cities)	Deaths, injury, stress disorders, asthma (fire smoke)	Flooding injuries and deaths +29-48% (does not include mental health)(12, 29)‡, fire deaths, injuries to increase (no estimates)	Flooding and fires to increase, health estimates not available
Drought and drying	Rural, remote, indigenous communities	Depression, suicide, asthma (dust storms)	Likely increase(30)§ No estimates	Likely increase(30)§ No estimates

* Assuming no further climate change, accounting for likely population growth and change in age profiles.

** New notifications per annum relative to baseline notifications assuming no further climate change, accounting for likely population growth and change in age profiles.

*** Percentage change from current notifications (assuming no further climate change, accounting for likely population growth and change in age profiles).

‡ High emission scenario, no change in population or age profile assumed.

‡ ‡ Based on central Indigenous population baseline, no population or age profile changes assumed.

§ Based on current mortality and morbidity studies, no estimates of future impacts provided.

Future estimates indicate that Australians will face significant additional health burdens (see Table 1). Heat stress and associated deaths are expected to increase (12). The range and seasonality of vector-borne diseases such as malaria and dengue fever may widen (12). As the frequency and severity of fires, cyclones and floods increase, so too will related deaths, injuries and mental disorders linked to loss and trauma (as yet, there are no Australian estimates of future impacts). The health impacts from the slow-moving disasters of desertification, rising sea levels and drought are most likely to be indirect but equally severe. Losses, hardship and chronic financial stresses are predictive of depression and anxiety, as is the experience of dislocation and community disruption (13).

The health impacts of climate change will impinge unequally between populations, countries and regions. Globally, the estimated 150,000 annual deaths in 2000 (from major selected causes of death), attributable to climate change that had occurred (relative to the 1961-1990 average climate), were almost entirely confined to the world's low-income nations with poorer and more vulnerable populations. Within Australia, climate change could also exacerbate existing health inequities (10).

Adaptive responses to climate change may not reduce the social patterning of health risk from climate change. Successful adaptation to climate change will require resources to counteract rising food, water and energy costs in Australia. The unequal distribution of money and resources and differences in the quality of living and working conditions put socially disadvantaged groups at greater risk of climate change-related health outcomes (10). People who adapt relatively successfully are therefore most likely to have the resources to do so; a growing pool of socially disadvantaged could face a much greater health risk because they do not have the resources to cope. In Australia, socio-economic disadvantage, living conditions and access to health services are stratified by location (remote, rural or urban). Loss of livelihood and the internal migration of rural families to cities may add further to this widening health differential, and within cities may exacerbate residential segregation by income. Australian cities are characterized by high housing costs, urban sprawl and spatial polarization, with low income households concentrated in the mid to outer suburbs. These suburbs often lack services essential to good health, amplifying the health risks flowing from low socio-economic status. Furthermore, exposures to climate-related risks vary by occupation and social status with, for example, low paid outdoor labourers and workers at heightened risk of heat stress (14).

CHILDREN'S HEALTH VULNERABILITY

There are very few estimates of the climate change-related health impacts for Australian children. However, it is well documented that children show greater exposures and sensitivity to extreme weather and heat events, vector-, food- and water-borne diseases and those associated with air pollution and aeroallergens (15). Because climate change is likely to increase these sorts of health risks, children are a population subgroup that will be particularly affected—another form of inequity.

Immature physiological systems increase sensitivity to air-borne pollutants, bushfire smoke and allergens (16). These are predicted to increase because of changing seasonal patterns, pollen production and vegetation (17). Recent Australian research shows that young children are prone to overheating, and that hot days can also increase likelihood of fever or gastroenteritis (18). Indeed, for every 1^{0}C increase in temperature there is a 3-8% increase in incidence of diarrhoeal disease, which will disproportionately affect children, especially those who are disadvantaged. A similar, close relationship between temperature and the incidence of vector-borne diseases has been observed in children, although to date they have not posed major health threats in Australia.

Children's immature neurobiology, along with their dependence on caregivers, adds another dimension to their vulnerability, and this is especially relevant for understanding the health impact of the expected increases in natural disasters in Australia, such as fires and flooding. Compared with adults, trauma exposure in childhood can lead to marked alterations in brain function and longer term cognitive and mental health impacts (19). Children surveyed six months after the 2003 bushfires in Canberra, which destroyed 500 homes, showed much higher rates of emotional and behavioural problems compared to Australian norms, with nearly half showing elevated Post Traumatic Stress Disorder symptoms (20). Furthermore financial hardship, trauma and loss associated with climate change-related disasters may affect parents' mental health, which may increase family conflict and erode the close and supportive relationships that are determinants of children's mental health (21). For example, in the US, rates of inflicted head injury to children under 2 years old increased five-fold after a hurricane (22). Even less is known about possible child age-specific impacts of climate change, including differences in vulnerability from exposures in infancy or *in utero,* relative to exposures in older children. Children's exposure to health risk and hardship is partly determined by their parents' socio-economic status; thus a widening gap between households in their access to income and other resources will be profoundly consequential to children.

Children in the developing world face the double jeopardy of climate change compounding extreme poverty, but even in an affluent nation like Australia children will show a greater vulnerability to health impacts. Some children currently confront compounding impacts linked to geography and socio-economic status, such as disadvantaged Indigenous children and those living in remote areas. Such compounding impacts will have ramifications for their future adult health quite different to the health trajectory of current adults. It is also likely that climate change will impact on the health of those as yet unborn, foregrounding the issue of intergenerational health inequities.

INTERGENERATIONAL HEALTH INEQUITIES

Intergenerational health inequity refers to the unequal and unfair distribution of health across generations. The term encompasses poorer health outcomes for children relative to adults, and the avoidable—through reasonable social action—differences in health between the unborn and people living now. Akin to the notion of sustainability, achieving intergenerational health equity would require that economic, social and health policies and actions must conserve the health and quality of life of children now and into the future, and of future generations (to paraphrase Edith Brown Weiss's 1989 definition of intergenerational equity) (23).

We argue that an intergenerational framework helps clarify the human health impacts of climate change because it encompasses three things: children's vulnerability to these risks (an age- and development-related element); increased health risk over ensuing decades, which children will confront as they age; and increased health risks over the longer term, experienced by future generations as yet unborn. We have already discussed children's age- and development-related vulnerability. The next section considers the expected future health differences that constitute a rarely considered form of health inequity: potentially avoidable disparities in health across generations (see figure 1).

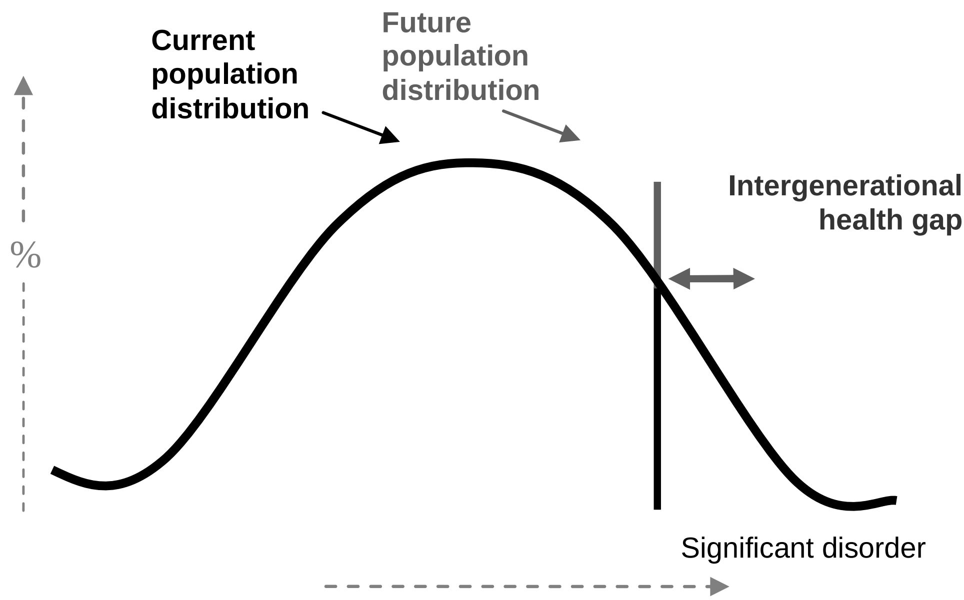

Figure 1. Hypothetical population distribution of mental health, current and future (2050).

To illustrate this aspect of intergenerational health inequities, we summarise estimates of the future health impacts in Australia in table 1, which contains available estimates for heatwave-related deaths and hospitalisations, bacterial gastroenteritis, dengue fever, and flood-related deaths and injuries. These estimates are based on either no or relatively little emission reduction; that is, they are for high emission scenarios and assume little or no mitigation. Relative to the current generation, Australians living in 2050 will confront a 30-100% increase in selected health risks; those living in 2100 face a 3 to 15-fold increase. Although these future estimates underline a likely, significant health inequity by generation, they are both incomplete and conservative. Many future health outcomes have not yet been estimated, especially the mental health problems related to social and economic stress, drought, natural disasters and loss. Nor are there quantified estimates of the interactions between the health risks posed by climate change and age or developmental status.

Figure 1 further illustrates the notion of an intergenerational health gap, using a hypothetical population distribution of mental health problems. Currently, 20% of Australian adults experience some type of significant mental health problem in a 12-month period (24). If climate change increases the prevalence of mental health problems, including prevalence of traumatic stress-related problems, it shifts the population curve. This will mean significantly higher numbers of people in future generations will experience clinically-significant disorder (the area marked by the line, under the future curve), creating a marked disparity in population mental health across generations. This figure is illustrative only, as the size of the intergenerational gap is not known and will depend on actions to reduce emissions, adaptation capacity and the resources available to prevent or treat mental health problems.

POLICY AND RESEARCH ISSUES

Compared with adults living today, future Australians may not only experience worse health on average but also may live in a society characterised by greater health inequity. Furthermore, Australian children will face over their lifetime an increase in climate change-related health risks. Even if CO2 concentrations were immediately confined to current levels, the amount in the atmosphere will keep increasing for at least the next 100 years (25). The extent of health risk that future generations confront, however, is not fixed, and some of the health impacts could be reduced by policy and intervention.

So far, Australian policy discussions of climate change do not directly focus on the consequences for children's health or on equity. Reducing avoidable health differences is a foundational principle in public health policy and health promotion, as well as a policy goal in an increasing number of countries worldwide. A report from WHO's Commission on the Social Determinants of Health (26) represents a global effort to compile evidence that will galvanize action to improve health equity. We argue that the health risk posed by climate change must also be viewed through the lens of health inequity and represents the additional policy challenge of closing the health gap across generations. Indeed, climate change may generate two types of health inequities. The first will lower population health overall across generations, including between adults and children living now. The second will widen the health gap and increase the social gradient in health, with those at the top of the hierarchy better able to adapt.

Lack of robust evidence contributes to the present paucity of attention to child health impacts and intergenerational equity issues. Although we know enough to act now, an important step in building an intergenerational health framework is developing age-specific and child-focussed health risk estimates. In Australia, we lack estimates in three critical areas: first, impacts of climate change on children's mental health; second, the extent the health effects of climate change will vary by location (urban, rural, remote, regional) and by family structure and resources (including socio-economic); and third, the way Indigenous children may be affected (climate change could threaten, for example, traditional food and cultural resources as well as exacerbate social and economic disadvantage). Additionally, age-sensitive periods for some exposures may exist, for example heat stress in infancy.

Viewing climate change as an intergenerational health inequality issue may also help channel public health resources towards adaptation and mitigation strategies, which can be viewed as health interventions as well as environmental ones. However there is no agreed methodology for policy analyses that considers future health. Economists handle the uncertainty involved in quantifying future states by making assumptions about expected returns, utility and value, and in some instances by discounting future utility and costs (27). Criticisms of this approach in relation to climate change are widespread and longstanding (28). It is equally doubtful that assumptions of diminishing value can be applied to health policies across generations, including the health of children.

Global bodies are beginning to recognise the importance of children's interests and health. Both the UNDP and UNICEF are developing environmental education resource packs for schools. The WHO has formed two initiatives: Healthy Environments for Children Alliance (HECA) and Children's Environmental Health Indicators (CEHI) to support action on children, health and environment issues and to improve the evidence base and monitoring of children's environmental health indicators. However, an intergenerational health framework is largely lacking in policy efforts and debate regarding climate change, including in Australia (29,30). Meanwhile, in an age of digital media and widespread internet access, children themselves are aware of the emerging problem posed by climate change, as illustrated by the quote opening this paper.

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Chapter 6

WARMING UP TO THE EMBODIED CONTEXT OF FIRST NATIONS CHILD HEALTH

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This chapter argues that the health and wellbeing of Indigenous children, their communities, and ultimately their nations, arises from connection with the land and from cultural strengths linked with this connectivity. We provide critical reflection on contemporary discussions about impacts that climate change will have on the social, ecological, cultural and historical determinants of health of Indigenous children in Canada. Our analysis highlights overlooked opportunities, perspectives and priorities that demand attention in order to prevent climate change from exacerbating the already unacceptable health inequities experienced by Aboriginal children across Canada.

INTRODUCTION

Although emerging against an almost unprecedented level of scientific attention (1,2), scholarship about climate change and health is – like all scholarship – a socially produced phenomenon. As such, there are certain risks associated with the ways that it is produced, oriented and circulated. Specifically, an emphasis on certain locales and peoples, has an associated risk of eclipsing certain other people and places. This paper aims to analyze existing scholarship, and propose interventions to redress these tendencies in the context of

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health of First Nations children in Canada. We begin with the premise that the health and wellbeing of Indigenous children, their communities, and ultimately their nations, arises from connection with the land and from the strength of culture that grows from this connectivity (3). We suggest that in many discussions about climate change, particularly those focused on worldwide and global scale models and outcomes, what is often overlooked are the lived, diminutive, embodied, and intimate health realities of places and people (particularly children) in rural and remote regions, or in geographies beyond major urban centres.

In the Canadian context, analyses of climate change that links the health and wellbeing of people to their locale often places particular emphasis on Inuit peoples and communities of the circumpolar north (4-7). This reflects a complex global-local discussion with far-reaching impacts on cultural, socio-economic and environmental determinants of health in the circumpolar north, involving shifts in temperatures, ice and climatic conditions, loss of permafrost, degradation of sensitive ecological habitats and species and, associatively, loss of traditional livelihoods and threats to community practices, infrastructure, food and water security (5,8-10). Rather than re-visiting these well-documented concerns, we locate, ground and emplace, discussions about the implications of climate change for health within geographies we suggest have not yet garnered the much needed attention in the growing scholarship about climate change and health.

Specifically, our paper provides a critical intervention that highlights certain peoples (children) and certain localities (specifically rural, First Nations' reserve communities). Our intent is to overcome the tendency for climate change research to prioritize notions of vulnerability and health hazards in relation to where the most dramatic impacts – and usually the most people – are situated. We off-set this risk by identifying three domains of literature not yet been fruitfully deployed to conceptualize the links between climate change and health, and highlight convergence toward a more nuanced understanding of the determinants of aboriginal health in general, and First Nations children in particular. We outline the methods used to guide this critical intervention and highlight why a re-scaling and relocating of discussions has the potential to change how health and climate change are thought about in Canada.

CONTEXT, BACKGROUND AND APPROACH

To (re)locate discussions about the impact of climate change on the health and wellness of Aboriginal children in Canada, we offer a brief, culturally and geographically specific, scenario that positions our analysis in the particular context of a First Nations child in rural British Columbia.

Consider for a moment then, the not-so-hypothetical case of Jada, an eleven year old girl living with her uncle, and attending Grade 6 in the small "Indian" Reserve community of Kitsum-Kalum, just outside the town of Terrace in northwestern British Columbia. Jada's grandparents have always reinforced the idea that her wellbeing is intrinsically tied to her cultural heritage, a critical component of which is preparing salmon each year when the salmon run in the late summer and early fall. The salmon runs are increasingly threatened due to an array of proposed factors, ranging from warming oceanic currents and river temperatures to transfer of diseases from coastal fish-farms to wild salmon (11,12). On the other hand, and not in opposition to her grandparents, Jada's uncle wants to ensure Jada gets a good education and lives in a house free of economic stresses. As a consequence, he is pleased about the growing jobs in forestry extraction availed to him because of the Mountain Pine Beetle epidemic that has devastated millions of pine trees to the east of his community, resulting from warmer winters that prevent seasonable die-off of the beetle (13,14). Jada's uncle is also pleased about what he believes to be longer, warmer spells in the summer because it means increased productivity in his back-yard garden.

First, this scenario transpires in a region not often specifically named in climate-change research. Naming of the local, and outlining of tensions at the local level, is imperative if the impact of climate change is ever to be fully conceptualized. We argue this scenario can only be meaningfully understood – and thus fully conceptualized – when and if it is theorized in relation to (i) the social determinants of aboriginal health, (ii) the links between ecosystems, equity and health, and (iii) a recognition of the intersectionality of the determinants of Jada's health. When taken together, the literatures about these topics allow for a "complexifying" (15) of the growing discourse and public rhetoric about health and climate change. In the context of Aboriginal children, this "complexifying" encourages scholarship that makes explicit local, place-based, and child-centred concerns.

The approach highlights voices and places that are still relatively quiet on the increasingly noisy, and highly political, stage of climate change and health. We consider not just the interplay between climate change and the social determinants of health inequities, but their combined relationship with land, water and natural resources. Landscape, after all, manifests through the soil, water, air, food, language, culture and living systems, as foundations for Indigenous child health. Discussions about climate change thus spur broader discussions about the social, ecological, cultural and historical determinants of Indigenous child health.

Our analysis is guided by the question - How is Jada's scenario left behind (overlooked) in contemporary constructions and discussions about climate and health? To respond to this question we undertake a critical analysis and synthesis of three emerging and complementary literatures relevant to understanding the impacts of climate change on the determinants of Jada's health. Innovative components of these literatures are contrasted with more dominant and pervasive discourse of climate and health. Key features of the analysis are summarized in table 1.

This method, a critical comparison and contrasting of climate change literatures and discourses, has implications for Jada, her community and the complex social-ecological settings and scales that determines her health and wellbeing, particularly First Nations children on reserve although by no means limited just to these people and geographies. This approach also begins to respond to an overlooked and under-evaluated need for longer-term research that focuses on the complex interplay between social determinants of Aboriginal child health and ecosystem change, including historical, cultural, socio-political, economic and ecological dimensions of the landscapes of Aboriginal children in Canada. As a contribution toward this, we three authors represent divergent and converging perspectives and experiences. We are an Indigenous scholar and director of Canada's National Collaborating Centre for Aboriginal Health [MG], a critical geographer in a faculty of medicine [SdL], and a Canada Research Chair in Health, Ecosystems and Society [MP]. Our collaboration represents what Woollard has described as the scholarship of integration - or "making connections across disciplines and, through this synthesis, advancing what we know"(16) and contributes to a growing body of work aiming to inform and improve the design of programs and interventions to promote the health and wellbeing of Aboriginal children in Canada and beyond (3,17,18,19).

Table 1. New neighbours – linking climate change with innovations in determinants of health.

Trend	Examples	Links with climate change literature
(i) Conceptualising Aboriginal child health holistically, in conjunction with innovations in framing determinants of Aboriginal health.	The Web of Being(18), holistic concepts of aboriginal child health,(3,19,51); health inequalities and Aboriginal People's Health (17, 21); First Nations Holistic Planning Model (52); Indigenous wholeness (53).	Some holistic models of Aboriginal Health are cross-references in analyses of health impacts of climate change for Inuit and Circumpolar peoples, but these links are poorly developed.
(ii) Connecting health, ecosystems and equity (understanding links between ecosystem change and social determinants of health)	Ecosystem Approaches to Health (also referred to as ecohealth) (31-35); health, environment and social equity (54); ecosystems as settings for health and sustainability (36, 37, 46).	Emerging against a strong tendancy to view equity and ecosystem impacts of climate change separately. Integrated analyses of climate impacts on social *and* ecological determinants of health are rare.
(iii) New theories such as intersectionality, highlight the interdependence of determinants of health.	Intersections of race, class and gender (55,56); the interaction and intersection of social categories and implications for lived social inequalities and disparities (38-42).	The attention to intersections among social variables is not yet well-linked with ecosystems and the physical environments, and tends to be distanced from climate change.

SYNTHESIS: CLIMATE CHANGE AND CONVERGING DETERMINANTS OF FIRST NATIONS CHILD HEALTH

Situating our analysis in Jada's reality enables an examination of climate change and First Nations child health to commence with a child who is embedded in a family and community, with a specific landscape and time. Each facet of her brief story helps to identify, and locate, how climate change may influence her health and wellbeing, and reinforce the relevance of new perspectives on climate change and health in Canada.

For some, whose primary interest may be child health, a starting point in considering Jada's health and wellbeing are health statistics. A recent report on the state of Aboriginal children's health in Canada (20) synthesises and highlights a series of grim prospects for Jada

– on-reserve First Nations children have immunization rates 20 per cent lower than the general population, First Nations teenage fertility rates are seven times higher than that of other Canadian teenagers, rates of Tuberculosis are 8 to 10 times higher in First Nations communities in comparison to non-Indigenous communities (19-21). For others, whose starting point is climate change, Jada's context may seem less concerning than populations considered more vulnerable or at higher risk to the impacts of changing climate. Yet when overlaid within three streams of literatures (see table 1), Jada's story provides important and valuable insights into understanding how disparities in Aboriginal child health, and the far-reaching impacts of climate change may continue to influence Jada's health and lifescapes.

A web of influences determining first nations child health

Jada's story provides an informative reference point to locate what Loppie, Reading and Wien have described as proximal, intermediate and distal determinants of health (17) and to what has also been depicted as an interrelated web of being (18). While similar to other conceptual models of social determinants and aboriginal peoples' health, Greenwood's relationship 'web' anchors the determinants of health in Indigenous knowledge(s) and personal experience. Jada and her family are situated at the heart of the web - a contextual place marked by specific land and family influences. Tightly linked within this core are a range of influences prominent in Jada's family life, including the availability of housing to her family (and its suitability to the northern BC climate), the level of education of Jada's mother and other caregivers, and her family's social support network. The land, soil, air and water of the reserve on which Jada lives are also core features of Jada's web of being - known most intimately through her favourite streams for swimming and salmon harvest. These micro-scale and embodied localities need to be named and accounted for when discussing climate change and health.

The close-up, individual and personal influences on Jada's life are also impacted by broader systems such as education, health, justice and social services. Thus, although Jada failed to progress to Grade 7 when her parents left the reserve in search of work in the oil industry in Alberta, she was convinced by her uncle to return to school and is progressing well. Jada admits that a key factor influencing her to return was her grandmother's involvement in a school science project linking fish, culture, health and language. This project was inspired by a "People, Place, Potential" newsletter (22) seen by Jada's teacher at the local health centre. Although less obvious to Jada, she and her family are also influenced by much larger historical, political, economic and social constructs. Jada's grandparents attended residential school, the impacts of which have influenced Jada's mother and uncle, and in turn, her whole family experience. The fact that Jada's family reside on reserve is testimony to the history of colonial occupation of the Americas; reserves were imposed spatial constraints with histories of ill-health, violence, and resilience (23-26). These complex and multifaceted relationships amongst the social determinants of health are depicted in Greenwood's web of being.

Jada's story highlights the nuanced, interweaving factors that feature in recent efforts to conceptualise determinants of aboriginal child health holistically (Table 1). These factors are also impacted by climate change in a range of positive and negative ways. Understanding

Jada's case, and using it as a starting point to levy very located, specific, and embodied questions about climate change and health, encourages an orientation to a child as being embedded in their family and community throughout their life-course, and insists that researchers understand that changes to the land and waterways on small, often overlooked reserves, resonate 'up' to regional logging operations, coastal fish dynamics and oil extraction trends in other provinces or even countries. This combined social and ecological understanding is relevant to Aboriginal health models and, when linked with new developments in understanding the complex impacts of changing climate, has the potential to reframe the way impacts of climate change are theorized in scholarship.

Re-introducing estranged neighbours – ecosystems, equity and health

Linking climate and health scholarship with place-based land, water and food concerns, and impacts on small, often unnamed and overlooked communities and economies, is congruent with emerging attention to ecosystem change and the social determinants of health inequities. The combined pressures of global climate change and resource degradation have spurred recognition that the "adverse health effects from human-induced environmental changes will be distributed unequally. The poor, the geographically vulnerable, the politically weak, and other disadvantaged groups will be most affected"(27). The WHO Commission on Social Determinants of Health expanded on this concern with high level calls to "bring the two agendas of health equity and climate change together"(28). This was followed by recognition of both synergy and conflict between the interelated concerns of addressing to climate change and health disparities (29).

Yet a focus on climate and health equity offers a limited perspective on determinants of Aboriginal child health, unless they are explicitly connected with the ecosystems and landscapes considered to be foundations of health and culture for Aboriginal communities. These imperatives are directly addressed in the report of the WHO Commission on Social Determinants of Health:

> "Indigenous People worldwide are in jeopardy of irrevocable loss of land, language, culture, and livelihood, without their consent or control – a permanent loss differing from immigrant populations where language and culture continue to be preserved in a country of origin. Indigenous Peoples are unique culturally, historically, ecologically, geographically, and politically by virtue of their ancestors' original and long-standing nationhood and their use of and occupancy of the land. Colonization has deterritorialized and has imposed social, political, and economic structures upon Indigenous Peoples without their consultation, consent, or choice." (28)

Ironically, the global discourse around climate change and health inequity can become both abstracted and divorced from these local ecological and social relationships and realities. In order to bring Jada's story into focus within the highly political and growing discourses about climate change, we argue for explicit recognition that ecosystems and equity are tightly coupled as determinants of health, and are central to understanding how climate change will exacerbate existing inequities in new and unpredictable ways. A dual focus on ecosystems and equity highlights what Parkes et al describe as a double-dividend for health (30). Several research trajectories have developed along these lines, including an orientation to environmental justice and health equity, and the emerging field of ecosystem approaches to health, also known as ecohealth, (31-35) and described as “participatory, systems-based approaches to understanding and promoting heath and wellbeing in the context of social and ecological interactions”(33).

Application of ecohealth approaches has highlighted the potential of viewing social-ecological systems as next generation ‘settings’ for health promotion, especially in the context of watersheds (36,37). When considering the impacts of climate on Jada’s determinants of health, such approaches explicitly re-connect and embed the land on Jada’s reserve within wider trends in natural resources management throughout the watershed and landscapes drained by the Skeena River - from British Columbia’s coastal mountains to the Pacific Ocean. This (re)focus highlights interrelated concerns regarding changes to water flows, temperatures and quality in both the river and in the coastal marine systems, and insists on attention to proposed spread of diseases from coastal fish farms to migrating wild salmon stock, with direct implications for the complex social-ecological connections between the salmon harvest and Jada’s family health and wellbeing. These multiple, dynamic, converging and overlapping issues cannot be extricated from each other, but can be meaningfully conceptualised if climate change is viewed as an overlay to other intersecting determinants of health.

Intersectionalities

As we have written elsewhere, one way to effectively conceptualize linkages between varied subjects – particularly if those subjects exist on the margins of social research or are divested of power in and by that research – is to reconceptualise them through a lens of intersectionality theory (see table 1). Broadly speaking, intersectionality is a theory that wrestles with, and attempts to explain, how socioculturally constructed categories (predominantly but not exclusively categories such as gender, ethnicity, and sexual orientation) interact with and impact upon one another to produce differentially lived social inequalities amongst peoples (38-42). Informed by growing evidence of the relevance of intersectionality theory to research concerning Indigenous people’s health (15) and and the myriad intersections between climate change and social determinants of health, our intention here is to highlight intersectionality as a timely, if not overdue, contribution to the understanding climate change and Aborginal child health.

The theory of intersectionality arose as a means to examine, in an increasingly nuanced and complex approach, the ways in which varied forms of otherness interact to produce differently striated realities of social marginalization and social exclusion (40). Intersectionality, then, can be broadly understood as a theory that accounts for the relationships between categories of otherness and the ensuing marginalization resulting from those relationships (43). For the purposes of this critical inquiry into the ways in which climate change research produces and reproduces certain hierarchies of understandings, we propose (and indeed have, fundamentally employed) intersectionaliy theory as a means of more fully theorizing and understanding the multiple scales, places, and peoples whose health is impacted – both positively and negatively – by climate change. Intersectionality, then, can assist researchers struggling with how to overcome traditional dichotomies in climate change and health research, including dichotomies that risk overlooking Jada's reality by emphasising binaries like vulnerability/resilience; past/future; social/ecological; mitigation/adaptation; people/place. We propose, instead, that Jada's reality is best understood when situated at the intersections of these dichotomies, from which climate change and health research might learn valuable lessons.

CONCLUSIONS

Through this brief critical analysis of climate change literature and discussions about the determinants of health, we have identified an important difference between what we describe as 'top-down' and 'bottom-up' approaches to understanding and responding to the impacts of climate change on the health of children. Top-down approaches to climate change and child heath tend to start with the concerning threats of global climate change and work down through various spatial scales and pathways to examine diverse impacts on the health of populations of concern, and possibly, to focus on vulnerable populations, including Aboriginal peoples and children. This dominant approach to understanding the impacts of climate change is reflected in a range of literatures in Canada and beyond (4,44,45).

The language and literatures associated with vulnerability, resilience and adaptive capacity have begun to inform this top-down approach, grounding the impacts of, and responses to climate change, in the lived realities of local people (7,46-48) and influencing how climate and health linkages are represented in large scale national and international reports (4,49,57,58). A recent initiative by a Canadian Indigenous Environmental network with an explicit focus on "Climate Risks and Adaptive Capacity in Aboriginal Communities South of 60 Degrees Lattitude", highlights that those outside of the health sector are also recognising the importance of these issues for aboriginal communities beyond Canada's circumpolar north (50).

A complementary and we would argue overdue approach to understanding climate change and aboriginal child health in Canada, are 'bottom-up' approaches where the starting point is a child embedded within a specific social and ecological context, who will experience climate change as one factor among many complex determinants of their health. We have presented three approaches that inform and deepen our understanding of these dynamics. While many of the issues of climate change and health may have generic relevance across Canada's Aboriginal children (including Metis and Inuit), a focus on Jada as a First Nations youth has oriented our analysis to the lives, communities and cultural identify unfolding within the specific, historically imposed units of land defined as reserves. Jada's scenario set the stage to illustrate the value of (re)grounding global unfoldings such as climate change in both new (or as of yet overlooked) geographies and in the context of health determinants.

There are important convergences and divergences in contemporary understanding about the impacts of climate change on the determinants of aboriginal child health in Canada. We have sought to highlight why a re-scaling and relocating of discussions has the potential to influence how health risks and adaptations linked to climate change are thought about in Canada, and especially those who are responsible for planning and designing interventions focused on the health and wellbeing of First Nations children. Such approaches enable an understanding of climate change as a pervasive and exacerbating layer of impact that may also serve to increase our sense of what is imperative when addressing existing health inequities for Aboriginal child health.

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Chapter 7

HEALTHY CHILDREN AND A HEALTHY PLANET: A ROLE FOR EDUCATION

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Climate change is an urgent global public health issue with substantial predicted impacts in the coming decades. Concurrently, global burden of disease studies highlight problems such as obesity, mental health problems and a range of other chronic diseases, many of which have origins in childhood. There is a unique opportunity to engage children in both health promotion and education for sustainability during their school years to help ameliorate both environmental and health issues. Evidence exists for the most effective ways to do this, through education that is empowering, action orientated and relevant to children's day to day interests and concerns, and by tailoring such education to different educational sectors. The aim of this chapter is to argue the case for sustainability education in schools that links with health promotion and that adopts a practical approach to engaging children in these important public health and environmental issues. We describe two internationally implemented whole-school reform movements, Health Promoting Schools (HPS) and Sustainable Schools (SS) which seek to operationalise transformative educational processes. Drawing on international evidence and Australian case examples, we contend that children's active involvement in such processes is not only educationally engaging and rewarding, it also contributes to human and environmental resilience and health. Further, school settings can play an important ecological public health role, incubating and amplifying the socially transformative changes

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urgently required to create pathways to healthy, just and sustainable human futures, on a viable planet.

INTRODUCTION

Climate change is recognized as a major threat to global health by leading scientific and medical journals (1,2), the World Health Organization and the Intergovernmental Panel on Climate Change (IPPC) (3). Notably climate change and its consequences threaten attainment of the United Nations Millennium Development Goals of reducing child mortality, achieving universal primary education, eradicating poverty and hunger, and ensuring environmental sustainability (3). Ultimately, from a global perspective, it is the poor and young people, especially in developing counties, for whom the implications of climate change are predicted to be most severe (2). Decisions and actions taken now will have intergenerational consequences, with delayed or uncoordinated global action on emissions reduction predicted to significantly increase risks to human survival and wellbeing, including costs and difficulty of adaptation (3,4). While not the complete answer, education has an important role in imagining a safe climate future, and transforming unsustainable patterns of living (5).

Australia is recognised as one of the developed countries most vulnerable to the impact of climate change (6). A recent analysis of environmental threats to children’s health in the Australian setting (7) identified the following potential impacts of climate change:

- changing patterns of infectious and vector-borne diseases such as dengue fever
- heat stress and health effects of extreme weather events such as fires, floods and cyclones
- effects of changing plant growth on allergen levels and asthma
- water and food insecurity
- pressure on children's mental and emotional health due to drought, concerns about climate change, and from traumatic exposures to fires, floods, and storms.

The report also noted that, compared with adults, children’s earlier and more prolonged exposure to climate change-related stresses over their lifetimes is likely to amplify these adverse health impacts.

Concurrently, global burden of disease studies highlight a range of chronic diseases, many having their origins in childhood (8). While children’s health has improved in many developed nations over recent decades, concerns include rising rates of childhood obesity, asthma and mental health problems (9). A “big picture” view incorporating the profound social changes occurring in the modern world helps in understanding the changes in young people’s health and wellbeing in rich countries. Family breakdown, media and technological impacts, dietary changes, and “cultural intangibles” like increasing individualism, excessive materialism and hyper-consumer lifestyles have been identified as part of the changing ecology of childhood (10,11). In drawing attention to links between such changes and children’s health, some commentators suggest that recent decades of dramatically expanding market-based economic growth have failed to deliver the social and environmental dividends that were promised (10,12,13).

Mental health problems are already the largest contributor to the burden of disease in Australia's young people (14) with evidence that these problems are growing and persisting into adolescence and adulthood (11). New research also shows that, along with more personal concerns about how they look, not fitting in, or bullying for example, children are concerned about the state of the world. A 2007 Australian Childhood Foundation survey of children 10-14 years, found that 52% were worried about not having enough water in the future, 44% about the impacts of climate change, 31% that they will have to fight in a war when they get older, while 36% were apprehensive about terrorism. The report found: "A quarter of children are so troubled about the state of the world that they honestly believe it will come to an end before they get older" (15). Children are particularly vulnerable to distress and anxiety associated with their growing awareness of the risks of climate change (16). Additionally, their parents' mental distress and anxiety in response to the direct and indirect impacts of climate change may result in negative impacts on parenting. The risk of child abuse and neglect, for example, is elevated following extreme weather events such as cyclones and tornados. These cumulative and interacting direct and indirect impacts mean that young children are at amplified risk of harm due to environmental stress. Therefore interventions promoting mental health and resilience in childhood, particularly those that build parent and community resilience at the same time may be effective in reducing the future burden of mental illness.

A ROLE FOR EDUCATION IN ADDRESSING PUBLIC HEALTH IMPACTS OF CLIMATE CHANGE ON CHILDREN

The fourth IPCC report (3), Britian's Stern Review of the economics of climate change (17), and Australia's Garnaut report (7) have heightened awareness of how the Earth's life support systems have been over-stretched, putting human health at risk. The urgent need for fundamental changes in how we live is increasingly obvious, although little systemic change is yet evident. While recognising that schools and education systems are already under pressure with competing and often contradictory demands and a "crowded curriculum", education must also equip children and young people to function and flourish in an uncertain world. Effective education for the twenty-first century will need to help them cope with and lead the social transformations required for a transition to a safer-climate, low-emission future.

However, learning based on worldviews that reinforce unhealthy, unsustainable lifestyles and environments is a significant part of the problem. “The crisis… cannot be solved by the same kind of education that helped create the problems” (18). Much recent educational reform is more about adapting educational policy to the demands of a globalised market economy - encouraging people to adapt to change rather than developing their capacities to shape change (19). If education is to be effective in socialising the young to become resilient, healthy individuals and active citizens in an ecologically-recovering world, we need transformative, transdisciplinary education to assist humans to understand and work within the Earth's ecological systems (6).

This chapter argues that children are capable of being active players in enacting the societal change processes required to meet climate change challenges. It contends that their participation will promote not only environmental sustainability, but also health and educational achievement. Evidence exists that the most effective ways to do this are through education that is empowering, action orientated and relevant to children's day to day concerns.

THE FOCUS OF THIS CHAPTER

This chapter describes two internationally implemented whole-school reform movements, health promoting schools (HPS) and sustainable schools (SS) which seek to operationalise transformative educational processes. Both HPS and SS derive their socially critical and emancipatory underpinnings from Freirian approaches that see education as a vehicle for personal, social, and political empowerment, as expounded in Freire's seminal work "Pedagogy of the Oppressed" (20). There is evidence that both approaches, separately, can be effective in either promoting health or educating for sustainability. This chapter, however, reflects on these two approaches and presents case examples drawn from the literature and from the authors' experience to argue that each would be strengthened, both in concept and in practice, by integrating with the other to holistically educate for health and sustainability.

HEALTH PROMOTING SCHOOLS (HPS)

Essentially, HPS is the application of a public health approach in school settings (21), moving away from single-issue, classroom-based health education, towards a more holistic and comprehensive approach. The HPS concept emerged in the 1980s and 90s through the World Health Organisation (WHO) in Europe, and the United States Centers for Disease Control, and is based on socio-ecological understandings of health and of schools as settings for health development (22-25). The global spread and local adaptation of the HPS concept can be traced through the reports of a series of technical and expert committee meetings and initiatives involving WHO, the US Centers for Disease Control and Prevention, and parallel organizations in education such as UNESCO.

Vince Whitman and Aldinger's 2009 "Case Studies in Global School Health Promotion" illustrates the many purposeful ways the concept has been utilized to address national and local health priorities in countries with differing challenges, cultures and circumstances (21). Health Promoting Schools are now found in Europe, the Americas, the Middle East, Asia, Africa, and the WHO Western Pacific Region, including Australia and New Zealand. The European Network for Health Promoting Schools, renamed Schools for Health in Europe (SHE Network) in 2007, is active in over forty three countries (26), while the ten-year-old United Kingdom Healthy School Standard program is recognized as a key delivery mechanism for UK national public health and social development initiatives such as the Children's Plan (2007) and Healthy Weight, Healthy Lives (2008) (27). At its best, HPS is a comprehensive, setting-based approach, reflecting the critical socio-ecological underpinnings of the WHO's Ottawa Charter for Health Promotion (22) and Sundsvall Statement on Healthy Environments (23), both of which drew attention to the links between empowerment, health and environment. In recognising the importance of environments, the Ottawa Charter identified as essential conditions and resources for health: peace, shelter, education, food and income, a stable eco-system, sustainable resources, social justice and equity (22). The settings approach shifts the emphasis from individual behaviour change towards community action in the everyday settings of life, to improve the broad determinants of health (22). A health promoting school is also described as one that is continually creating and improving the physical and social environments that strengthen its capacity to be a healthy setting for living, learning, working and playing (28). As such, it is always a work in progress.

Key principles for HPS are: upholding social justice and equity; student participation and empowerment; creating safe and supportive school environments – both physical and social; and, linking health and education issues and systems. Ideally, HPS model, in microcosm, how a healthy and sustainable world might function. The approach promotes wellbeing and learning through:

- curriculum - active, participative classroom practices
- environment/ethos - improving a school's physical and social environments
- community partnerships - forging partnerships with parents, local community and relevant community agencies (24).

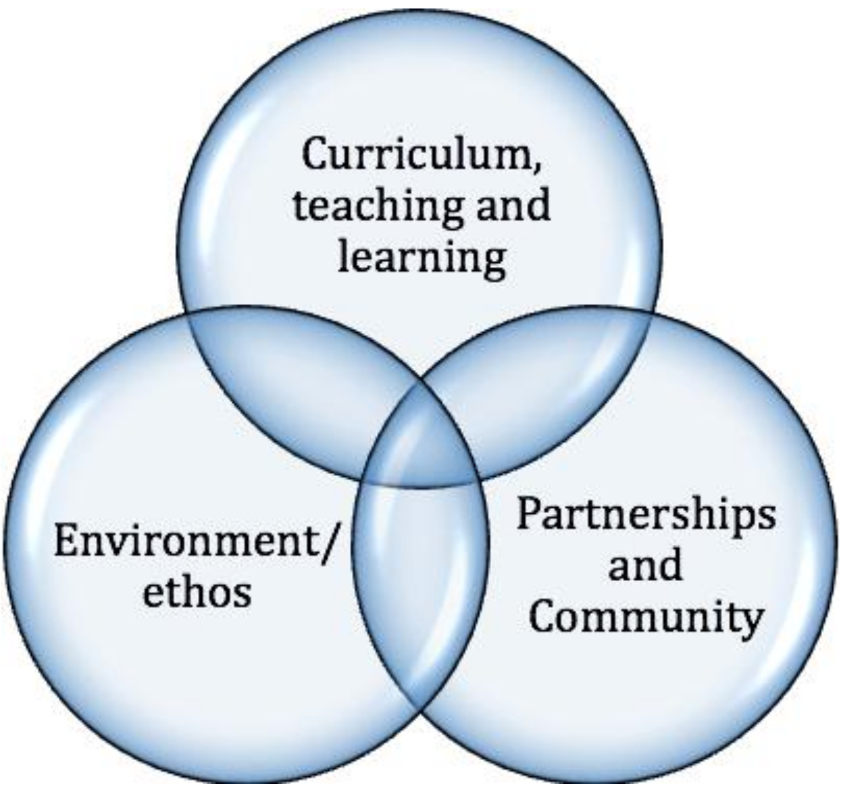

Figure 1. HPS components.

HPS COMPONENTS

Participation is central to success. By including everyone, and in particular, children, the democratic HPS process allows groups with different agendas to come together to identify common interests, and achieve shared goals. This builds cooperative, social skills in both adults and children. Through mediating between competing interests, it builds ownership, commitment and a sense of community. Stewart et al (30) found that a Health Promoting School environment that creates a strong sense of autonomy and builds "connectedness" between adults and children and between children and their peers, is a major contributor to children's psychological resilience. With its focus on active student participation, the process also recognises that even very young children can be competent thinkers about issues that impact on their lives and wellbeing. It helps develop student and community abilities to take action for change, for healthier lives and healthier living conditions. This "action competence" (31) grows through critical thinking, planning, and real-life experiences of action-taking to improve the relevant health issue or situation (see Box 1, a primary school example). In this way, children are personally involved in creating a better, healthier, and more enjoyable classroom, playground, school, community or world. Such experiences of "making a difference" build individual and collective empowerment, self-efficacy and mental wellbeing (32).

BOX 1.

Students in a socio-economically disadvantaged metropolitan primary school in Queensland, Australia addressed unhealthy eating patterns by instigating a "Kids Kafe" through the school's tuckshop, as part of a HPS program. This project was initiated when the tuckshop/canteen had to be closed for one of the three days it had been previously operating, due to diminishing parent volunteer assistance. Students in Year 7, becoming bored with their lifeskills afternoon cooking program, identified that they might be able to assist the tuckshop by providing a healthy "meal deal" for one day each week. A student committee was formed and began setting up a small business venture. With help from their teacher and teacher aide, they designed the menu, advertised, took orders, purchased ingredients, cooked the meals, set tables, served the meals and cleaned up. Positive outcomes identified by the school community included:
• Student learning that spanned many academic and social areas including literacy, numeracy, health and life-skills, workplace health and safety, cooking, budgeting, and running a small business.
• Students throughout the whole school learning about nutrition and hygiene.
• Parents opting for the healthy meal choice when allowing students to spend money at school (33).
In addition, the project provided opportunities to enrich relationships between teachers, parents and students thus increasing community connectedness and enhancing the health promoting capacity of the school. Furthermore, the area adjacent to the tuckshop was redeveloped to create a comfortable, shaded outdoor eating area that has improved the amenity and social climate for students, staff and families by providing a friendly and accessible venue for many school community events. "The whole community responded to the experience and pavers were painted by them, fired, and placed on the area to be known as Kidz Kafe" (School principal) (33).

An important aspect of health promotion and HPS is that participants implement the concept flexibly, in response to their own locally identified needs, to meet their own goals, as illustrated in box 2.

BOX 2.

Staff at a nearby, large secondary school recognized that the HPS concept offered a new way to address their concerns about student lack of motivation, negative attitudes and poor learning outcomes (33). The school community began their engagement with HPS through extensive data-gathering involving staff, students, school nurse and parents. A variety of participatory strategies was used to investigate student and community perceptions and needs, and to identify relevant priority issues. Although this took a long time, over twelve months, the process gave confidence to the participants that subsequent activities were based on data and not preconceived ideas of health issues and concerns (33). It also ensured broad student and community “buy in” through their engagement in the data gathering, analysis and discussion of findings. This helped build good participation in the projects subsequently developed to address student absenteeism, mental health resilience, alcohol and substance use, and promote help-seeking behaviour among students and families, among others. Results include changes to school policies (wellbeing and ‘behaviour management’), ethos and teaching practices, so that the lessons learned from the process continue to inform and improve the way the school works.

There is sound evidence of the effectiveness of comprehensively-implemented HPS programs for improving health outcomes, particularly related to healthy eating, physical activity and mental health (34). In Australia, major national educational curriculum and professional development programs utilizing HPS include the National Nutrition Education in Schools program (1995), Mindmatters (2002) and KidsMatter (2006). Moreover, the benefits of HPS extend beyond health. A review of National Healthy School Standard school evaluations in the UK found improvements in learning environments, student concentration and performance, staff health and wellbeing, and student school achievement (35).

SUSTAINABLE SCHOOLS

While environmental education and education for sustainability are not entirely new fields – they share a history going back to the 1970’s - the comprehensive, whole school approach exemplified by international movements variously called Eco-schools, Green Schools, Enviro-schools and Sustainable Schools (SS) is a more recent development, and less well established and coordinated than HPS. Broadly, Sustainable Schools (as it is called in Australia) encourage schools to achieve measurable social, environmental, educational and financial outcomes by:

- going beyond awareness raising to action learning and integration with school curricula
- encouraging the involvement of the whole school
- encouraging the involvement of a school’s local community and encouraging a shift in the broader community towards more sustainable practices and processes
- developing relationships with other areas that impact on the organisation and management of a school

- being founded on a sound basis of theory and practice in schools and school systems, quality teaching and learning, environmental education for sustainability (see http://www.environment.gov.au/education/aussi/about.html#principles).

Sustainable Schools make a direct contribution to the United Nations Decade of Education for Sustainability 2005-2014 (36) by encouraging and supporting schools to develop a culture of sustainability. Underpinned by critical theoretical approaches aimed at challenging the status quo and creating active, informed citizens, SS implement improvements in their management of resources and grounds, and integrate this into the existing curriculum and daily running of the school. The goal is that students participate in action learning within the school as a "learning organization" in which people at all levels, individually and collectively, continually increase their capacity to produce results they really care about (37). While still in its early days, initial evaluations (38,39) are encouraging. In one country school in Victoria, Australia for example, the amount of waste sent to landfill was reduced by 90%. As in HPS, SS schools are also reporting broader social and educational benefits from increased school pride, interest and involvement in learning. Box 3 highlights two examples of this process.

BOX 3.

A class at a public school in Sydney, Australia promoted "No Waste Lunches" after taking part in a waste audit. Children are encouraged to bring a healthy lunch such as sandwiches and fruit in an airtight container. Eighty five percent of the students now bring a healthy lunch on a regular basis. Food scraps are placed in the class's worm farm and children are rewarded with certificates if they bring 25 "No Waste Lunches" (40).
A similar "litterless lunch" program in a Queensland kindergarten that has been implementing a "Sustainable Planet Project" for over ten years, resulted in a reduction of waste from 2 large bins/ day to half a bin/day (41). Recently, the three to six year olds in this kindergarten have been exploring the concept of global warming. Outcomes of their discussions – they already have some knowledge as a result of media exposure and family talk - and their problem solving led to increased public transport use by families and correspondence to and from the Prime Minister of Australia around their concerns and calls for change (42).

GREEN AND HEALTHY SCHOOLS: THE CASE FOR INTEGRATING EDUCATION FOR HEALTH (HPS) AND SUSTAINABILITY (SS)

Human health and the health of the planetary ecosystem are interdependent, and educating for health and for sustainability, have much in common. It is logical to integrate health education with education for sustainability. Both use holistic whole-setting approaches and involve parents and community. Both are participatory and action-based. Both are student-centred and empowerment-focused for addressing real-life, health and environmental issues of importance to the children in their local settings and neighbourhoods. Indeed, there is a growing list of educational initiatives which have health goals in mind, and which also meet education for sustainability goals: e.g. creating "green" outdoor play and learning spaces promotes mental and social health and provides for physical activity (health issues), and also enhances contact with nature (environmental issues) (6).

Research has identified a range of educational and well-being benefits of schools with "green" grounds, "learnscapes", edible school gardens and other opportunities that integrate classroom and outdoor learning in nature (43,44). In general, demonstrated benefits of gardening and other learnscaping activities include increased play opportunities, engagement and reflective citizenship, safety, social inclusion, better relationships with the natural world, and increased environmental stewardship. There are also benefits for learning and academic performance, and for curriculum and classroom management (43,44).

One example from a public school in a disadvantaged area in Sydney (Australia) illustrates the power of such approaches on individuals, as well as on school ethos (see box 4).

BOX 4.

After a unit of work entitled "Gardening for All Seasons" which combined science studies on weather and how plants grow, one student at educational and social risk, and who was failing school, attended a school working bee with his father to help establish a "no dig" permaculture garden. The student became more engaged in the program and settled into a positive and successful behaviour pattern at school. At the end of the school year, his father reported that, at his son's instigation, they had made a garden at home and re-established their relationship to the extent that the program had "given me my son back" (40).

Integrating education for sustainability's explicit focus on the natural environment increases the salience of health promotion and health education in schools. It provides processes that go directly to the heart of many of today's student anxieties about the world and their future in it. The multiplier effect of early childhood influences on lifelong development and health (10) means that programs integrating health promotion and education for sustainability in early childhood settings such as child care and kindergartens may prove equally or even more beneficial than those in schools (32). Intrinsic to both HPS and SS approaches is their close, bi-directional relationships with parents and the broader community. This means that not only are children actively engaged in interesting educational work that fulfils learning, health and environmental needs, but the flow-on effects include community engagement and learning, and community capacity building, often highly valued by those involved. Furthermore, schools can learn from, and help each other, to implement such integrated processes, as illustrated in box 5.

The case examples presented here and other evidence from the research literature support the contention that active participation in identifying and addressing issues and topics of concern to students and their communities is not only educationally rewarding, it also contributes to human and environmental resilience and health. Such hands-on approaches to education for sustainability and health promotion, including for example, school kitchen gardening initiatives, not only improve schools' educational effectiveness and outcomes - a school's core business - but are intrinsically engaging and enjoyable to students, their families and communities. Moreover, they can help restore children's connection to the natural environment, while nurturing hope, physical and mental health, and personal and collective efficacy to respond to challenges. In so doing, kindergarten and school settings can play an important ecological public health role, incubating and amplifying the socially transformative changes required to create pathways to healthy, just and sustainable human futures, on a recovering planet.

BOX 5.

A community of schools in Sydney, Australia - consisting of a high school and three partner primary schools - joined together between 2006 and 2009 to develop an integrated set of curriculum materials about climate change. The project, "Cool in Campbelltown", was one of a number of Department of Education and Training action research programs run across the state. The schools worked in partnership with the local city council and an environmental education centre. While initially the work was focused on students and teachers in Years 5-8, it was later expanded to include Years 4-9. Not only did the students learn about the science of climate change, they also felt empowered to take a proactive stance in relation to the topic. This in turn helped them maintain a hopeful outlook and positive attitude towards their future. Primary students made a film about students' preconceived ideas of climate change and its causes. This gave a baseline to measure the level of increased understanding at the end of the unit. The film was shown as part of a student film festival at a local cinema. Year 9 students from the high school took part in an English unit on "The Language of Persuasion." They created a campaign called "Global Warming – Global Warning." Students made television commercials, documentaries, wrote children's books and designed bumper stickers and tee-shirts. The students presented a workshop to principals at a regional principals conference highlighting their work and demonstrating their learning. Students have also run activities for students from other schools as part of a Sustainable Schools Expo, which runs annually in the region (40).

As noted, HPS and SS share the same socio-ecological foundations and transformative orientations. By working together to create 'green and healthy' schools that nurture human and environmental resilience simultaneously, schools can play a constructive role in creating green and healthy futures. While not easy to do, these examples show that it is possible and that the returns are rewarding. However, there are structural and cultural barriers to cross-sectoral partnerships between health, education, and environment which need to be further broken down. Within schools, a crowded curriculum, and pressure to focus on narrow outcomes such as literacy and numeracy at the expense of transdisciplinary concepts like sustainability, citizenship and health, limit opportunities for such educational innovation. The lack of attention to transdiciplinary learning and teaching also pervades preservice teacher education and teacher professional development. This has led to a teacher workforce ill-equipped to support the curriculum and pedagogical approaches required for holistic learning and teaching. Similarly, health professionals need further skills to partner respectfully and effectively with educators, students and communities, and to embrace ecological, holistic and empowerment paradigms that capitalize on the strategic public health and environmental gains that can be achieved.

Furthermore, small scale changes within individual schools and local communities need to be connected into a large scale movement if green and healthy education is to take hold. What is needed to scale-up and fast-track the processes more broadly within education is for the adoption of a systems approach to creating change. This requires both top-down and bottom-up strategies, for example support at national Health, Education and Environment Ministry levels, at regional policy levels (21), and practical implementation assistance at local authority and school levels. Such support would include an explicitly central, rather than marginal, place for ecology/environment and wellbeing in curriculum frameworks, mandated time allocation, quality guidelines for green and healthy schools, new teacher standards and professional development to support participatory education approaches, curriculum and teacher materials, and human and financial resources. A good example of the latter is provided by the United Kingdom Healthy Schools Standard which has funded and guided partnership development between local health and education authorities. Governance organizations in Health and Education, including teacher and health professional registration authorities, Health and Education faculties, curriculum development organisations, employing authorities and other systemic partners, must all work together to create cultures of sustainability in Education and Health. Such system-level support is vital for guiding and supporting the changes needed to confront the current and emerging health and environmental challenges, in tandem with the motivation and energy of individual school communities, and health organizations.

CONCLUSIONS

Whole-school, empowerment and action-oriented approaches such as those outlined in this chapter have the potential to engage children, families, teachers and communities in helping to change society's direction. Truly transformative change is urgently needed and HPS and SS have the potential to be important contributors. Working together to create green and healthy schools plays a constructive role in creating green, just and healthy futures.

This emerging field - at the intersection of health promotion, environment and education - presents new opportunities for effective public health approaches to preventing the worst effects of climate change. It also has the potential to create innovative and vibrant partnerships for interdisciplinary action and research, including action research approaches, into how educational interventions can promote positive responses to current challenges. Australian and international evidence is growing that active involvement is not only educationally rewarding, it contributes to both human and environmental resilience and health. Such holistic innovations, rather than approaches embedded in narrow, discipline-based or economically rationalist thinking, can result in schools whose students and communities can lead change, rather than resisting or following it. Practitioners and researchers in education, health and environment will be important in building and testing the evidence base for transdisciplinary education in a range of settings including cities, megacities, suburban, rural and remote environments and communities. The case examples described in this chapter attest to the fact that educational settings can also play an important ecological public health role, incubating and amplifying the socially transformative changes required to create pathways to carbon-constrained, safe climate futures, on a recovering planet.

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Chapter 8

CLIMATE CHANGE AND DIARRHOEAL DISEASE: PERSPECTIVES FOR DEVELOPMENT POLICIES

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This chapter points to the key role of health in development programmes and illustrates through diarrhoeal diseases as a case example, how climate change can impose increasing risks, which particularly will hit young children and the poor. The increased incidence can both be expected to emerge from higher temperatures and from more extreme events in particularly flooding. The number of people affected is by WHO projected to be approximately 700,000 dead and 22 mill disability adjusted life years in 2030 without climate change, so it is very important to initiate climate change adaptation measures that can help to reduce these risks. An attempt to start such a process i.e. has been done by the Danish Overseas Development Assistance Programme, Danida, which has conducted a climate screening of programme activities in Bangladesh. The chapter presents a number of conclusions from this climate screening related to climate proofing of Danida activities in the water supply and sanitation sector.

INTRODUCTION

The nexus between climate change and human health is extensive and complex. Climate change is expected to affect human health in a variety of ways; for example directly through diseases linked to temperature changes (e.g. heat strokes) and through changes in precipitation and water systems. New areas can be affected by vector borne diseases such as malaria at higher altitudes, and flooding events together with higher temperatures can increase the incidence of water borne diseases. This together with stress on food access and thus nutrition enhances health vulnerabilities.

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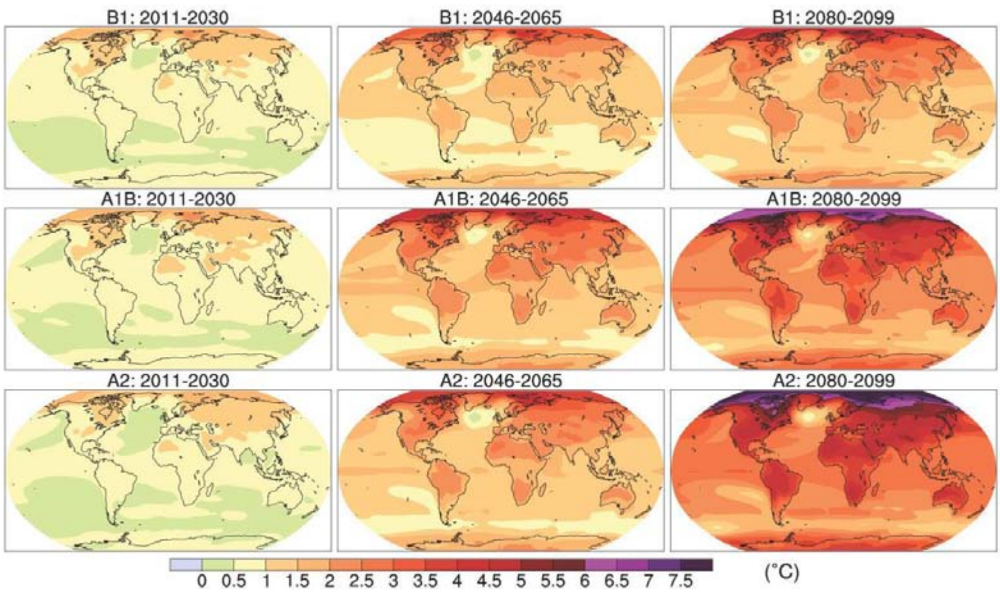
Our climate is changing, and these changes will increase in the coming years, due to inertia in the climate system, where the current changes are the results of atmospheric greenhouse gas concentrations that have been built up over the last 100 years (1) (see figure 1). An ambitious international agreement on emission reductions will significantly reduce these impacts over this century, but whatever happens, short term climate change adaptation is needed. The health sector is a key element in development programmes, and it must be considered as one of the sectors that are particularly vulnerable to climate change. This paper will provide a number of examples of these vulnerabilities.



Source: (1), figure 10.8. Note: Multi-model mean of annual mean surface warming (surface air temperature change, °C) for the scenarios B1 (top), A1B (middle) and A2 (bottom), and three time periods, 2011 to 2030 (left), 2046 to 2065 (middle) and 2080 to 2099 (right). Anomalies are relative to the average of the period 1980 to 1999.

Figure 1. Annual mean surface warming.

MILLENNIUM DEVELOPMENT GOALS AND VULNERABILITY OF THE POOR

The importance of the health sector in development programmes was clearly stated by the United Nations, when 189 nations adopted the Millennium Development Goals (MDGs). One of the aims of the MDG's is to focus UN and national development efforts. There are eight overarching goals, and three of them directly address health. The MDGs are:

- Goal 1: Eradicate extreme poverty and hunger
- Goal 2: Achieve universal primary education
- Goal 3: Promote gender equality and empower women
- Goal 4: Reduce child mortality

- Goal 5: Improve maternal health
- Goal 6: Combat HIV/AIDS, malaria and other diseases
- Goal 7: Ensure environmental sustainability
- Goal 8: Develop a Global Partnership for Development

Similarly, health is a key element in the Human Development Index (HDI), where one out of three HDI measures relate to health. As is reflected both in the MDGs and in the HDI, health thus clearly is a crucial part of development, both in its own right and related to other aspects of development. Health status of children is explicitly important in both – the MDG 4 deals with child mortality, and the HDI measure with life expectancy at birth.

Health status is hugely important for economic development and poverty reduction. Mortality and morbidity can lead to children and families being trapped in a vicious poor health – poverty circle. Poverty means lack of access to basic health services and typically bad nutrition, and thus less resistance to diseases as well as less ability to cope with disease. This again leads to poor health, limiting their options for participating in education and the labour market, thus maintaining poverty. Also, for poor families, costs related to health services typically make up a large share of income, and often families will have to sell assets or take children out of school in order to be able to cover medical expenses. This leads to entrapment in poverty, and round it goes.

CLIMATE CHANGE AND HEALTH IMPACTS

Climate change impacts on all aspects of society, and health is clearly one of them. When the climate changes some health related problems will become smaller, such as cold-related deaths, but these will by far be outweighed by increases in other areas, such as water and vector borne diseases, heat related morbidity and mortality and injuries and deaths following increases in the frequency and intensity of extreme weather events.

Climate change is already today estimated to be responsible for 150-170,000 (2,3) deaths annually around the world. The burden of disease is typically measured in disability adjusted life years (DALYs), which take account of years of life lost due to death as well as losses of healthy time due to disease or injury. Climate change causes a significant amount of DALYs, and it is estimated that in 2000, climate change was responsible for 5.5 million DALYs, according to the WHO (4). It is especially responsible for deaths and DALYs of children under five. According to the WHO, 86 % of deaths and 88 % of DALYs attributable to climate change in 2000 occurred amongst children below the age of five (5). These figures were estimated as part of the WHO study “Comparative Quantification of Health Risks” from 2004, which evaluated several major risk factors’ influence on the burden of disease on a regional and global level. One of the risks considered was climate change, and the study (3) estimated how many lives and DALYs were attributable to climate change in 2000, and how many there would be in the future – until 2030.

Another way to look at future health impacts of climate events is to examine the past extreme weather events that are a major stress to health as a background for addressing what could happen in the future with more extreme events emerging from climate change. As it can be seen from table 1 below, on average, more than 200 million people have been affected by weather/climate related disasters annually, from 1990 to 2008, and among these disasters droughts and floods have affected most people and in particular those living in developing countries. Both these types of events will be closely linked to health impacts. Another category of events in Table 1 is epidemics. The number of people affected here is not very large, however this does not need to reflect that this is not a major problem, it rather might reflect that the database behind the numbers are related to disaster management, and the occasions reported in this context predominantly are those related to disaster risk management operations (6).

Table 1. Top 20 countries with the highest number of people affected by climate related events 1990–2008.

		Grand total, in millions	Drought	Earthquake	Epidemic	Extreme temperature	Flood	Mass movement (wet and dry)	Storm	Other
1	**China**	**2207,46**	311,41	62,24	0,01	7,90	1481,63	0,02	344,22	0,03
2	**India**	**901,45**	351,18	5,56	0,35	0,00	512,15	0,22	31,95	0,04
3	**Bangladesh**	**147,95**	0,00	0,00	2,21	0,19	114,76	0,00	30,77	0,03
4	**Philippines**	**70,20**	2,85	1,97	0,01	0,00	7,55	0,29	56,16	1,36
5	**Thailand**	**49,07**	23,50	0,06	0,00	0,00	22,57	0,01	2,93	0,01
6	**Kenya**	**44,61**	35,70	0,00	6,87	0,00	2,04	0,00	0,00	0,00
7	**Iran**	**40,84**	37,00	1,37	0,00	0,00	2,30	0,00	0,17	0,00
8	**Viet Nam**	**32,24**	6,11	0,00	0,02	0,00	16,84	0,00	9,27	0,00
9	**Ethiopia**	**31,04**	29,09	0,00	0,05	0,00	1,89	0,00	0,00	0,01
10	**Pakistan**	**29,41**	2,20	1,25	0,02	0,00	23,98	0,00	1,97	0,00
11	**United States**	**22,81**	0,00	0,03	0,41	0,00	0,92	0,00	20,67	0,78
12	**Malawi**	**19,86**	18,25	0,00	0,05	0,00	1,56	0,00	0,00	0,00
13	**Korea Dem Rep**	**18,72**	0,00	0,00	0,00	0,00	10,22	0,00	0,49	8,00
14	**Cambodia**	**17,13**	6,55	0,00	0,42	0,00	9,26	0,00	0,00	0,90
15	**Sudan**	**16,54**	11,36	0,01	0,08	0,00	2,49	0,00	0,00	2,60
16	**Australia**	**15,67**	7,00	0,01	0,00	4,60	0,07	0,00	3,94	0,05
17	**South Africa**	**15,64**	15,30	0,00	0,10	0,00	0,12	0,00	0,11	0,00
18	**Mozambique**	**15,51**	6,04	0,00	0,31	0,00	6,76	0,00	2,40	0,00
19	**Zimbabwe**	**13,94**	13,16	0,00	0,52	0,00	0,27	0,00	0,00	0,00
20	**Brazil**	**13,88**	12,00	0,00	0,85	0,00	0,85	0,01	0,15	0,01

Source: Own calculations based on data from (7)

DIARRHOEAL DISEASES AND CLIMATE CHANGE

One of the most serious health impacts as previously said will be water borne diseases such as diarrhoea. This section considers the incidence of diarrhoea and its potential relationship to climate change and presents a framework for measuring the costs of these incidences. The discussion is based on a general study (3), that investigated links between climate change and health, and this is supplemented by findings from Bangladesh, where severe and more frequent flooding events over the past decades have caused increasing diarrhoea events. Finally, some experiences are provided from Overseas Development Programmes that have done an attempt to integrate climate change risks, from which lessons can be learned about adaptation measures.

In that study (3) five links between climate change and health were identified and investigated; cardiovascular diseases, diarrhoeal diseases, malnutrition, malaria and unintentional injuries related to floods. Of the links between climate change and health considered in the study (3), diarrhoeal disease was the second largest link in 2000, with an estimated mortality of almost 50,000 and 1.5 million DALYs. The WHO has estimated that overall diarrhoeal diseases accounted for approximately 2.2 million deaths and 78 million DALYs in 2004, which equalled 3.7 and 4.8% respectively of the total estimated burden of disease that year (8). In 2030, WHO predicted that there would be approximately 700,000 deaths and 22 million DALYs if the climate did not change. The majority of deaths caused by diarrhoea occur among children under the age of five, and the disease is the second largest killer of young children (9). Diarrhoea is thus a big health issue related to children. With climate change and resulting predicted increases in temperatures and floods, the occurrence of diarrhoeal diseases is likely to increase, and human and economic costs will increase with them.

In order to estimate the diarrhoea cases attributable to climate change, McMichael et al (3) looked at the expected temperature increases in the 17 WHO regions, and calculated the relative risk of diarrhoea for alternative climate scenarios relative to baseline climate. The relative risks span from 1 to 1.09 (with confidence intervals spanning from 0.91 to 1.19). It should here be noticed that the scenarios applied in the study are from 2000, but the newest climate scenarios published by the IPCC project much higher temperature increases than those used by McMichael et al (3); hence, the increases in diarrhoeal disease are likely to be more dramatic than predicted.

In the McMichael study (3) a dose-response relationship of 5 % was applied in relation to diarrhoea in developing countries (per capita income <US$6,000 per year), meaning that a 1 degree centigrade temperature increase would be associated with a 5% increase in diarrhoea cases. In developed countries the dose-response relationship was assumed to be 0. The projections included projections for economic development, and as soon as a country grows beyond the US$6,000 per capita per year limit, the country is assumed to face the 0 dose-response relationship – i.e., the country will no longer be affected by increases in diarrhoea cases due to climate change.

One of the consequences of climate change in addition to the impact from increasing temperature also is an increase in the occurrence and strength of extreme events, including flooding – both coastal and inland. Flooding is a big source of spreading of waterborne diseases such as infectious diarrhoea. It is important to notice that the study does not include diarrhoea cases expected to be the result such events, or, for that matter, changes in precipitation. It looks exclusively at cases resulting from changes in mean temperature. However, McMichael et al (3) did investigate the health risk associated with increased frequency and intensity of extreme events, but increases in waterborne diseases such as diarrhoea are not calculated among the consequences.

The economic costs of diarrhoea are large, and they relate to several issues. Costs are both direct and indirect, and they accrue to a variety of parties. One of them is the cost of lives lost. A standard way of measuring the cost of a lost life is to discount the number of productive years lost, and value them by either the GNI per capita or the minimum wage – which one then assumes is the minimum cost per year of the lost life. Other costs associated with (increased number of) diarrhoea cases include the following:

- Full health care costs, including consultation and treatment.
- Costs the patient and family incur in relation to the visit to a health facility, including transportation costs, expenses on food and drinks, and opportunity cost of time.
- Productivity effect of cases resulting in illness but not death, typically valued at opportunity cost of time (10,11).

In conclusion, there could be large benefits to society associated with controlling these diseases, and many of the adaptation options will be closely related to ongoing ODA programmes in the countries. Some insights from current flooding events and diarrhoeal diseases in the following are provided for Bangladesh followed up by a screening of how health measures can be integrated in development programmes. The experiences are based on experiences from climate screening of the Danish Development Assistance Programme (Danida) in Bangladesh.

FLOODING EVENTS AND CHOLERA INCIDENCES IN BANGLADESH

Cholera is a particular water-borne disease linked to flood events, which has been seen in Bangladesh over and over again. In Bangladesh, there are significant intra and inter annual variations in outbreaks of cholera. Large outbreaks are associated with floods (12,13), as cholera bacteria have a natural habitat in water bodies, and water and sanitation infrastructure is inadequate. Bangladesh is particularly vulnerable to floods, and flooding is a common phenomenon in the country. Some years the floods are much more dramatic than others, and they have disastrous consequences. Some of the recent, most disastrous floods affected more than tens of millions people and killed several hundred each time, as illustrated by data for selected years presented in table 2.

Table 2. Number of people affected and killed by floods in Bangladesh, selected years.

Year	Killed	Tot. Affected
2007	1,230	13,851,440
2004	761	36,871,700
1998	1,050	15,000,050
1995	741	14,718,331
1993	194	15,751,613
1988	2,440	45,000,000
1987	2,280	29,700,000
1984	1,200	30,000,000
1980	655	10,000,000

Source: (7)

Additionally, they contributed to epidemics. The International Centre for Diarrhoea Diseases Research, Bangladesh (ICDDR,B) is situated in Dhaka, a city with more than 10 million people, where it facilitates treatment of diarrhoea to more than 100,000 patients each year. During the 2007 flood in the months of July and August, the ICDDR,B received up to 1,000 severe diarrhoeal patients per day, of which 30% of them were confirmed cholera cases. In a normal year, the centre would admit about 200 severe diarrhoea case a day (14). According to the WHO, experts estimated that Bangladesh has more than 1 million cases of cholera each year, though these are not reported to the WHO (15).

If the relationship between floods and cholera outbreaks continues to hold, then, as floods get more frequent and more intensive due to climate change in the coming decades, cholera epidemics will also increase in both frequency and intensity.

SUGGESTED CLIMATE PROOFING OPTIONS

Much of the cholera cases and projected increase in diarrhoeal disease related to climate change can be avoided by proper and timely adaptation measures. It is estimated that 88 % of diarrhoeal cases today are attributable to unsafe water supply and sanitation (16). Improving these conditions as part of an overall development strategy could therefore contribute significantly to avoiding increases in diarrhoeal disease cases due to climate change, but also cases occurring without climate change. Measures to combat diarrhoeal disease outbreaks and limit their consequences include both preventive and reactive measures (17), such as :

- Improved health impact monitoring for water and sanitation projects
- Improved tube wells which are adapted to climate change and disaster risks
- Information about the use of drinking water
- Water cleaning devices in the case of flooding
- Improved health services
- More general efforts to prevent flooding
- Improvement of data and forecasting methods

The approach of integrating climate risk management into development measures which can help society to adapt to climate change is called mainstreaming. To put it simply – development policies and initiatives must be well adapted to climate and climate change, since some of the key development sectors are among the most climate sensitive (18:767). A number of practical examples of how this can be done were suggested by a review of the Danish Development Assistance Programme, Danida in 2007 (17). It was in this context as a first attempt suggested to adjust ongoing and future planned Danida water supply and sanitation support in Bangladesh in order to integrate specific climate change proofing measures such as:

- Improved design of wells and other sorts of water supply options in order to take care of flooding risks, salinity intrusion, and decreasing ground water floor.
- Training of water/sanitation officers on climate change risk management.
- Capacity building for improved climate data use which i.e. can extend the time period for flood warnings.
- Development of government planning guidelines for integrating climate risks in development projects.
- General public awareness.
- Support to health clinics and research about waterborne diseases.

CONCLUSIONS

Human health is a crucial indicator of development, and this paper has pointed to some of the ways that climate change is expected to have important consequences for human health and children’s health in general, and thus development. Links between climate change and health include temperature increases and increases in the frequency and intensity of floods, and statistical data for the occurrence of extreme events since 1990 demonstrates that many people are likely to be seriously affected in the future. Furthermore, the paper has pointed to the large private and societal costs associated with diarrhoeal disease, and this all together is an obvious case for already today considering how climate health risks can be integrated in development programmes. Experiences from climate screening of development programmes in Bangladesh suggest that there are several areas within water supply and sanitation programmes, where climate change risk management should be integrated.

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Chapter 9

FLOODING AND INFECTIOUS DISEASE IN RURAL CHILDREN

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Flooding has the potential to trigger disease outbreaks from the sudden and severe disruption to both natural and built environments. As a result of global climate change, extreme weather events such as flooding are predicted to occur with increasing frequency and intensity. Populations at particularly high risk include those who live in areas prone to natural disasters, vulnerable groups such as children, and communities with poor resources to cope with additional stresses. In this paper we examine the mechanisms by which flooding can increase the risk of a wide range of infectious diseases, with particular focus on the high vulnerability of children who live in rural areas. The potential long-term significance of these infections, the importance of ongoing disease surveillance post-disaster, and the current gaps in knowledge regarding the long-term health impacts of natural disasters are also discussed. It is essential to improve public health infrastructure, enhance surveillance systems, encourage research on the immediate and long-term health impact of natural disasters, improve our understanding of the environmental drivers of disease emergence, and build capacity to cope with the increasing threats of infectious disease as a result of environmental and climate change.

INTRODUCTION

Ecosystems provide services essential for life, and damage to ecosystems has led to the emergence of many infectious diseases around the world. Acute high impact events such as flooding have the potential to trigger disease outbreaks from the sudden and severe disruption to both natural and built environments. As a result of global climate change, extreme weather

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events such as flooding are predicted to occur with increasing frequency and intensity (1). Populations at particularly high risk include those who live in areas prone to natural disasters, vulnerable groups such as children, and communities with poor resources to cope with additional stresses.

Despite the significant health outcomes that can result from ecosystem damage, there is currently little evidence to convince policy makers that protecting and restoring ecosystem services will improve health (2).

In this chapter, we will examine the mechanisms by which flooding can increase the risk of a wide range of infectious diseases, with particular focus on the high vulnerability of children who live in rural areas. We will also discuss the potential long-term significance of these infections, the importance of ongoing disease surveillance post-disaster, and the current gaps in knowledge regarding the long-term health impacts of natural disasters.

FLOODING

Flooding is the most common natural disaster in the world, and is expected to occur with increasing frequency (3). From 2004 to 2008, flooding and tropical cyclones were responsible for 40% of natural disasters around the world, and about 120 million people are currently exposed to tropical cyclones each year (1). Seventy percent of these disasters occur in Asia, the Pacific Islands, Africa and Middle East, where the majority of the world's most vulnerable populations live (4).

The risk of flooding is determined by the interaction between rainfall, sea level, local topography catchment size, and surface run-off. These factors can in turn be modified by land use, urbanisation, deforestation, agriculture, irrigation, dams, waste disposal, and water management practices (5). As a result of global climate change, additional factors which will increase the risk of flooding in some areas include rising sea levels, rising sea and land surface temperatures, increasing frequency of extreme weather events, more intense tropical cyclones, and larger storm surges (1). Anthropogenic environmental change can therefore combine adversely with natural phenomena to significantly alter the risk of flooding in both urban and rural areas.

The United Nations predicts that the world's population will increase from 6.7 billion in 2007 to 9.2 billion in 2050 (6). The combination of unprecedented growth and development, together with global climate change, is expected to increase the frequency, intensity, and impact of flooding around the world (1). The Intergovernmental Panel on Climate Change predicts that by 2080, the world's population at risk of flooding will increase by two to three fold, and rising sea levels alone will potentially account for coastal flooding that can affect 100 million people each year (1).

FLOODING AND INFECTIOUS DISEASE TRANSMISSION

This dramatic increase in flooding is likely to affect the incidence and prevalence of infectious disease, which is already on the rise because of emerging and re-emerging pathogens. Infectious diseases are currently responsible for significant morbidity and mortality in children around the world, particularly in developing countries. Each year, 4 million children under the age of five die from just three major diagnoses caused by infectious agents: diarrhoea, malaria, and pneumonia (7).

Flooding can increase the risk of infectious diseases by disrupting public health services and infrastructure, damaging water and sanitation networks, displacing populations, damaging homes, and increasing environmental exposure to pathogens (8). Overcrowding and poor hygiene in post-disaster shelters and camps can also promote the transmission of pathogens (9). On a larger scale, flooding can also disrupt ecosystems and cause or exacerbate the emergence or re-emergence of known or novel pathogens.

Disease outbreaks after cyclones are more likely to occur in developing than developed countries, and factors contributing to this increased risk include pre-existing high endemic rates of infectious disease, poor immunisation rates, and inadequate nutrition.The failure of public health services therefore increases the incidence of preventable disease. Lack of resources to cope with the recovery process will also lead to prolonged overcrowding and disruption of health services (9,10). In order to reduce disease burden post-flooding, it is therefore important to improve public health infrastructure and build capacity to cope with unexpected external stresses, particularly in countries with pre-existing high vulnerability.

A wide range of infectious diseases has been associated with flooding and other natural disasters. Some infections are more likely to occur during the acute post-disaster period, while others can be reported months or even years later, or even lead to a variety of long-term health complications. Examples of each of these will be discussed below.

Other factors that can mediate the risk of infectious disease post-disaster include pre-existing health status, socioeconomic circumstances, access to health care, post-disaster surveillance, population displacement, conflict, political unrest, community resilience, and adaptive capacity (8,11,12). Perhaps most importantly, there is a significant difference in risk, intervention, and resilience between urban and rural areas, with children in rural areas suffering disproportionately, as will be discussed next.

INFECTIOUS DISEASE IN RURAL AREAS

The environmental drivers of infectious disease differ between urban and rural areas, and it is important to appreciate these differences in order to understand the potential effects of natural disasters on the epidemiology of communicable diseases in different ecological settings. This understanding is also crucial for the planning and implementation of the most appropriate control strategies, which could vary for in different environments even for the same disease (13).

In cities, the dynamics of infectious disease transmission and emergence are influenced by factors such as population growth, urbanisation, overcrowding, poverty in urban slums, air pollution, waste management, and the rapid transport of pathogens via international travel and trade. Although the same drivers can operate in rural areas, arguably of far greater importance in the latter are land use practices.

In rural and farming areas, changes in land use (e.g. deforestation, agriculture, livestock farming, and mining) have the potential to cause environmental degradation, which can drive infectious disease emergence if ecological thresholds are exceeded. Encroachment of humans on wildlife habitats can promote the emergence of zoonotic diseases, or cause species of animals to become endangered. Extinction of animal species can disrupt the ecological balance between predators and prey, and lead to the dominance of species that serve as reservoir hosts for infectious diseases. For example, hunting reduced the population of wolves in the USA in the early 1800s, which in turn led to a dramatic growth in deer population due to the loss of predator wolves. Deer serve as hosts to ticks that carry Lyme disease, and the increase in deer populations is associated with the rise in incidence of Lyme disease in humans (14). Wolf hunting therefore led to the emergence of Lyme disease by disrupting the ecological interaction between animal species.

Water management practices such as irrigation, dams, and drainage can also affect the population size and density of animals and insects, potentially altering the transmission dynamics of infections such as rodent-borne or mosquito-borne diseases. Although outdoor air pollution and smog are less likely to be a concern in rural areas, indoor air pollution from the use of household solid fuels in developing countries is responsible for significant health problems, particularly respiratory infections in young children (15). Other air-borne irritants and allergens in rural areas that can pose health risks include organic dusts (e.g. from silos and barns), moulds, pollens, animal dander, fertilisers, pesticides, and mining dusts (16).

Disparity in health status between urban and rural areas has been noted in both developed and developing countries, and can affect the population's vulnerability to infections, and the consequences of those infections. In the United States of America, rural children are likely to be poorer, uninsured, inadequately immunised, and have inferior access to health care compared to their urban counterparts (17). Rural residents generally have longer distances to travel to health facilities, fewer visits to doctors, less ready access to medical specialists, and are less likely to engage in preventative health activities (18). If plumbing and sewage facilities are inadequate, flooding will also increase the risk of faecal-oral infections by washing pathogens into the environment, thus increasing the risk of contamination of drinking water and human habitats. Rural residents in the USA are more likely to have septic tanks and incomplete plumbing facilities, which has been associated with a higher incidence of diarrhoea (16,17). In Australia, rural populations also have poorer access to doctors, medical specialists, and allied health workers, and infectious diseases found to be more common in rural and remote areas include salmonellosis, pertussis, and Ross River Virus (19). Flooding can potentially enhance the transmission of all of these infections, as will be discussed below.

In developing countries, urban households are twice as likely to have piped drinking water and improved sanitation facilities compared to those in rural areas (7). Furthermore, malnutrition in children is more likely in rural areas, compounding their already high risk of infectious diseases. A survey of 15 countries in sub-Saharan Africa revealed that malnutrition and stunting were more prevalent in rural compared to urban areas (20). Similarly, over 50% of children in rural Bangladesh are stunted for age (21).

Flooding in rural areas therefore has the potential to drive the emergence of a wide range of infectious diseases, and disease burden will be compounded by the generally poorer infrastructure, inferior pre-existing health status, and limited access to healthcare compared to urban areas. Children are particularly vulnerable to this increased risk because of their susceptibility to infectious diseases and the associated complications.

THE VULNERABILITY OF CHILDREN TO INFECTIOUS DISEASE

There are many factors that make children especially vulnerable to infectious diseases post-flooding. Their behaviour can potentially put them at greater exposure to infections, e.g. poor personal hygiene can increase the risk of faecal-oral infections and wound infections, increased time spent outdoors can increase the risk of mosquito-borne diseases, playing in water can increase the risk of water-borne diseases, and more direct contact with animals can increase the risk of bites, rabies, and other zoonoses. Children are also more vulnerable to the effects of disasters because of their poor ability to adapt or respond to external stresses, and their dependence on adult caregivers (11,12).

Children are generally more biologically susceptible to some infections due to their naïve immune systems, or more likely to develop serious complications from an infection (11,12). However, there are exceptions such as Hepatitis A and chickenpox, which generally produce a milder clinical illness in children compared to adults.

Young children are particularly vulnerable to nutritional shocks, which can result from the disruption of food supplies during and following flooding (21). Environmental destruction can also lead to long-term disruption in local food production, and result in long-term food shortages and malnutrition in children. Nutritional deficiencies can weaken children's immune systems and predispose them to infections, as well as serious complications and mortality from those infections (8). For example, Haiti is particularly prone to flooding because of the combination of widespread deforestation and the frequency of hurricanes. Severe storms and flooding in Haiti in 2008 destroyed a third of total rice crops, as well as other crops and farming equipment (22). In a country that is already suffering from a food crisis, this is likely to lead to long lasting effects on nutrition, particularly in children. Following Hurricane Gilbert in Haiti in 1988, the increase in incidence of malnutrition and paediatric mortality continued for a year after the disaster (23).

Pregnant women are also more susceptible to many infectious diseases and more likely to suffer from severe complications. For example, malaria in pregnancy is associated with high rates of maternal mortality and fetal death-in-utero, as well as intrauterine growth retardation, which indirectly increases the susceptibility of newborns to infectious as well as other diseases.

As mentioned above, flooding in rural areas is likely to be associated with a high burden of disease from infections. Children in rural areas, especially in developing countries, are therefore an even more vulnerable group, and are likely to suffer disproportionately from infectious diseases both in the acute phase and in the long-term. Figure 1 illustrates how the above factors combine to increase infectious disease burden carried by children in rural areas, and the increasing risk as a result of climate change and flooding.

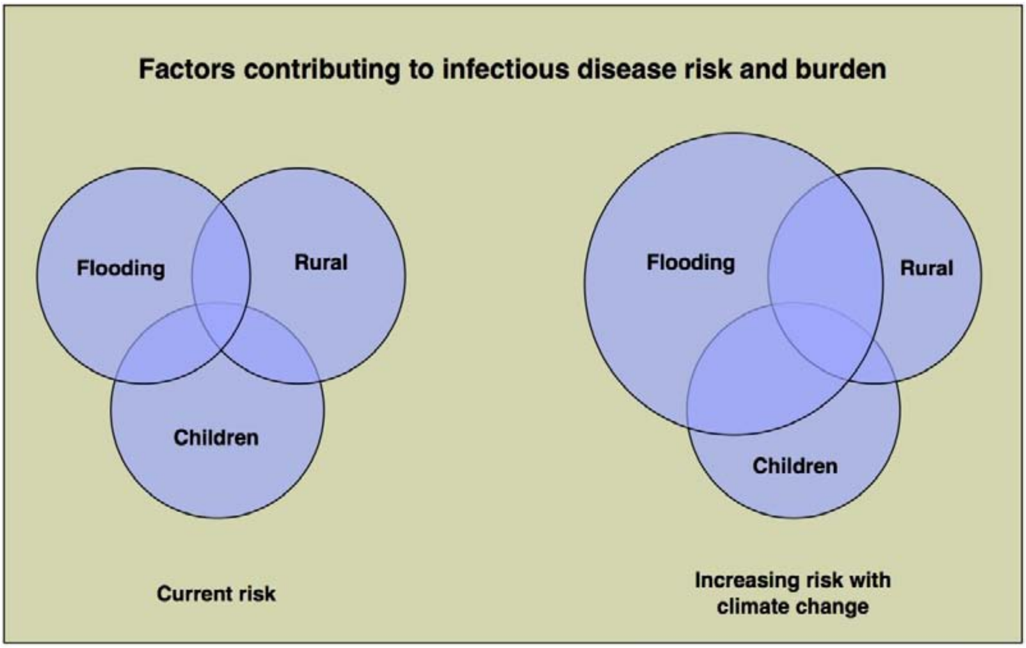

Figure 1. Flooding and disease burden in rural children.

More intense disease surveillance is therefore warranted in children, with particular attention to conditions that are expected to cause the greatest burden of disease. To assess the long-term impact of flooding on child health, ongoing monitoring is of paramount importance.

INFECTIOUS DISEASES ASSOCIATED WITH FLOODING

Having set the scene with preceding discussions of flooding and infectious disease in rural areas, we will provide examples of infectious diseases that can be exacerbated by flooding, and use them to illustrate the complexity of potential long-term health consequences, particularly in children. Some examples are drawn from disease outbreaks that have occurred after disasters other than flooding, but the principles of disease transmission are likely to be applicable under similar post-disaster conditions.

1) Faecal-oral infections

Flooding and natural disasters can increase the risk of faecal-oral infections by disrupting and contaminating drinking water supplies, damaging sanitation and sewage networks, and increasing environmental exposure to pathogens. Poor sanitation and overcrowding in post-flooding shelters also provide conditions favourable for gastrointestinal disease outbreaks.

Outbreaks of many gastrointestinal infections have been reported after flooding and other natural disasters. These include non-specific diarrhoea, hepatitis A and E, enterotoxigenic E. coli, cholera, shigellosis, typhoid, paratyphoid, cryptosporidiosis, rotavirus, soil-transmitted helminths, Giardia, and polio (8,10,24). Some infections such as Hepatitis A have long incubation periods, and will not present until weeks or months after the acute phase of a disaster (9).

After severe floods in Bangladesh in 1988, surveillance data and hospital admissions showed that diarrhoea was the most frequent cause of death (24). Outbreaks have also been reported many months or even years after a natural disaster. Following hurricane David and Fredrick in the Dominican Republic in 1979, outbreaks of gastroenteritis, hepatitis, typhoid, and paratyphoid were reported 5 months after the acute event (8). After the earthquake in Armenia City, Colombia in 1999, victims remained in temporary housing for two years after the disaster, and a high prevalence of Giardia was found among children in the disaster camps (25). Too often, disaster relief post-flooding is focused on immediate assistance with little consideration for such long-term effects. In order to identify long-term health impacts of flooding, it is critical to strengthen infectious disease surveillance after flooding (8).

Gastrointestinal infections in children are generally more severe, and more likely to lead to complications such as dehydration, systemic illness, and even death. Chronic infection with pathogens such as Giardia and helminths can also cause anaemia, malabsorption, and failure to thrive. Such complications can result in long-term health consequences in children, as well as increasing their predisposition to additional infectious diseases. These potentially long-lasting effects on child health are poorly studied to date, again reinforcing the need for long-term surveillance to inform intervention.

2) Vector-borne diseases

Flooding and environmental disruption can increase the risk of vector-borne diseases by creating conditions (e.g. pools of stagnant water, blockage of drains) that promote the breeding of mosquitoes and other insect vectors, or increase the geographic range of vectors (8). Other factors at play include the destruction of homes leading to more intense environmental exposure to insects; disruption of vector and malaria control programs; lack of medications for the prophylaxis and treatment of malaria; and disruption of health care and public health services.

Numerous outbreaks of malaria and dengue fever have been reported after flooding. For example, increases in malaria incidence were seen post-flooding in Latin America in 1982, and in Mozambique in 2000 (12). Dengue fever outbreaks have occurred after heavy rainfall and flooding in many countries around the world including Thailand, Indonesia, Venezuela, and Brazil (8). After severe flooding in Hat Yai City (Thailand) in 2000, dengue accounted for 29% of fevers in 180 children (26). In the rural tropical north of Western Australia, outbreaks of Murray Valley Encephalitis are commonly seen after flooding. In 1993, record rains and flooding were followed by the largest recorded outbreak, which mostly affected children (27). Outbreaks of Ross River Virus and Barmah Forest Virus are also associated with high rainfall in northern Australia, and are predicted to occur with increasing frequency as a result of climate change (28). Arbovirus outbreaks have also been associated with flooding in Europe, USA, and Africa (24).

Dengue is found in urban and peri-urban areas in most tropical and sub-tropical areas around the world. Recently, the incidence of dengue has increased dramatically around the world, and dengue haemorrhagic fever has become a major cause of morbidity and mortality in children in Asia (29). Factors that may have contributed to this increase in disease incidence and severity include population growth, urbanisation, overcrowding, increased frequency of flooding, rising temperatures, and the spread of Aedes mosquito vectors responsible for the transmission of the dengue virus. The exponential growth in international travel has also contributed to the recent spread of the four strains of dengue fever around the world, resulting in concurrent outbreaks with multiple strains, thereby increasing the risk of dengue haemorrhagic fever.

Children also bear the greatest global burden of disease from malaria, particularly in rural areas in developing countries. More than 40% of the world's children are at risk of the infection, and malaria accounts for 1 in 5 childhood deaths in Africa (30). Of the 1 million deaths from malaria around the world each year, three quarters are seen in African children less than five years of age (30). Apart from the acute illness, malaria can also have long-term consequences such as recurrent fevers, anaemia, and permanent neurological problems including epilepsy, blindness, spasticity, and cognitive impairment. Ongoing surveillance and data collection post-disaster is therefore crucial for assessing the true burden of disease caused by malaria outbreaks (8).

3) Air-borne and respiratory infections

Children are more likely to drown during floods, or suffer from the consequences of near drowning including respiratory infections and pneumonia. In addition, crowding in post-disaster shelters can increase the risk of air-borne infections. After the eruption of Mt Pinatubo in the Philippines in 1991, over 100,000 people were evacuated to resettlement camps, resulting in a measles outbreak involving more than 18,000 cases (31). Measles was responsible for 22% of deaths in the first 3 months post-disaster, with most of these occurring in a tribal group with low rates of immunisation against measles (31). Other air-borne infections that can potentially cause outbreaks after disasters range from meningococcal disease that can be rapidly fatal, to chronic infections such as tuberculosis (10,31).

The World Health Organisation estimates that there are over 9 million incident cases of tuberculosis each year, with approximately 1 million of these occurring in children. Severe complications from tuberculosis (such as meningitis, osteomyelitis, and miliary tuberculosis) are also more likely to occur in young children (6). The disruption of tuberculosis vaccination and treatment programs post-flooding can contribute to an increase in disease incidence, particularly in combination with overcrowding and poor nutrition (31). Tuberculosis has a long incubation period, and infection might not be become clinically apparent until months or even years later (9). Long-term surveillance post-disaster is essential to detect any increase in disease incidence, and direct clinical management as well as public health control measures (8).

4) Zoonotic diseases

Rainfall, flooding, and natural disasters can potentially influence animal population density and behaviour in different ways. On one hand, rodents and other animals might proliferate due to the scattering of garbage, debris, and food; the disruption of sewage and waste management systems; and stimulation of vegetation growth resulting in an increase in food availability (8). On the other hand, flooding can destroy animal habitats and reduce their population size. The way in which climate change will modulate existing animal behaviour (e.g. feeding, migration, and reproduction) is complex and dynamic, and will depend on multiple environmental and ecological factors as well as the animal species involved.

Flooding can also transiently increase contact between animals and humans while the animals have been driven out of their usual domain, and people have been displaced from their homes (32). Because of their small physical size, young children are at increased risk of severe animal bites, which can result in serious soft tissue infections or even rabies. An increase in the incidences of dog bites was seen after the Guatemala earthquake in 1976 (8). Children might also fail to report minor bites to their adult carers, and therefore not receive appropriate post-exposure vaccination against rabies.

Proliferation of rodents post-disaster can also increase the risk of zoonoses including leptospirosis, hantavirus, and plague (8, 24). After severe flooding in Hat Yai City (Thailand) in 2000, leptospirosis accounted for 27% of fevers in 180 children, and over 50% of fevers were caused by leptospirosis and/or dengue fever (26). Similarly, dengue and leptospirosis together accounted for 68% of total acute febrile illnesses after the Puerto Rico hurricane in 1966 (33).

5) Physical injuries and soft-tissue infections

Injuries are common during and after flooding, and children are likely to be a particularly high risk because of their poor ability to protect themselves. Wounds in children are more likely to become infected because they are less careful with keeping their wounds clean, generally have poorer hygiene standards, and more susceptible to infections. Poorer availability of health care and medications in rural areas can also result in delays in treatment, thus increasing the risk of infection and the severity of the complications.

Lacerations, bruises, fractures, and other injuries can result from falls, being hit by objects in fast-flowing waters, and being washed away by floodwater. Disruption of electrical power and damage to buildings and infrastructure will also increase the risk of accidents. Furthermore, heavy rainfall and flooding can cause landslides, avalanches, and increase the risk of motor vehicle accidents, all of which will add to the disease burden from injuries. As discussed above, near drowning will also increase the risk of respiratory infections.

Injuries and open wounds increase the risk of soft-tissue infections as well as more serious infections such as tetanus (particularly in communities with poor immunisation rates). After the tsunami in Aceh in 2004, a cluster of 106 cases of tetanus was reported, resulting in 20 deaths (10). Breaks in the skin will also increase the risk of acquiring water-related systemic infections such as leptospirosis and melioidosis (12).

6) Blood-borne and sexually transmitted infections

In areas where blood-borne infections such as HIV, Hepatitis B and C are highly endemic, the risk of transmission can be heightened after a disaster. Injuries sustained during flooding and the recovery process will increase the risk of infection through open skin wounds, and also increase the need for high-risk medical procedures such as blood transfusions and surgical interventions. In developing countries, particularly in rural areas, this risk is compounded by the poor quality of infection control in health care facilities, unreliable screening of blood products, and inadequate supplies of medical equipment including clean needles and syringes.

Children are also vulnerable to sexual violence and exploitation both during and after disasters, and therefore exposure to sexually transmitted infections. At the acute phase of a disaster, separation from family and social disruption increases the risk of sexual assault, abduction, and trafficking. During the recovery phase, children might be forced into prostitution as a desperate means of survival, or be exploited by child sex tourists and even relief workers or peacekeeping personnel. Children at greatest risk include those who have been separated from their families, disabled children, and those belonging to displaced populations or minority groups. Poverty also increases children's vulnerability to harm. It is therefore important to protect children not only during the acute phase of a disaster, but also to safeguard them in the longer term (34).

LONG-TERM HEALTH IMPACTS OF INFECTIOUS DISEASES

As illustrated above, the potential long-term implications of infectious diseases after flooding are significant and varied, and include: (i) infections which occur weeks or months after a disaster, (ii) infections with long incubation periods which might not become apparent until a much later time, and (iii) infections which can cause long-term health consequences.

Despite these risks, limited information is available on the long-term health impacts of natural disasters, and there is insufficient evidence to confirm the effectiveness of current public health recommendations or strategies for maintaining health after the acute phase of a disaster (8). Even less information is available on the additional effects on more vulnerable groups such as children (9), who warrant long-term surveillance post-flooding.

Collection of health data can be a challenge in the post-disaster period, when health systems are disrupted and public health resources are already stretched. This is particularly difficult in developing countries where health information systems are poor, or where surveillance systems have not previously been established. Lack of baseline information on disease epidemiology will also make it difficult to determine disease outbreaks post-disaster, or to assess the burden of disease attributable to the disaster. Strengthening of infectious disease surveillance systems is therefore crucial in order to effectively inform and direct public health interventions aimed at minimising health impacts of flooding.

MITIGATION STRATEGIES

Strategies aimed at reducing the burden of infectious disease associated with flooding can be divided into preventative measures that are put in place in preparation for a disaster, emergency response during a disaster, and control measures implemented after the disaster. In addition, ecosystem health monitoring and environmental hazard monitoring can provide warning signs for infectious disease outbreaks that might not be detected by routine disease surveillance alone. For example, leptospirosis outbreaks frequently occur after flooding, particularly in areas with an abundance of rats. Monitoring for the risk of cyclones and flooding as well as the density of rat populations will therefore give us addition warning signals for leptospirosis outbreaks that will not be captured by routine health surveillance. In order to maximise the effectiveness of pre-flooding mitigation strategies, it is essential to establish public health infrastructure for disease surveillance as well as develop tools for monitoring ecosystem health and environmental hazards. Figure 2 illustrates the multilevel intervention strategies that can operate at different stages of flooding.

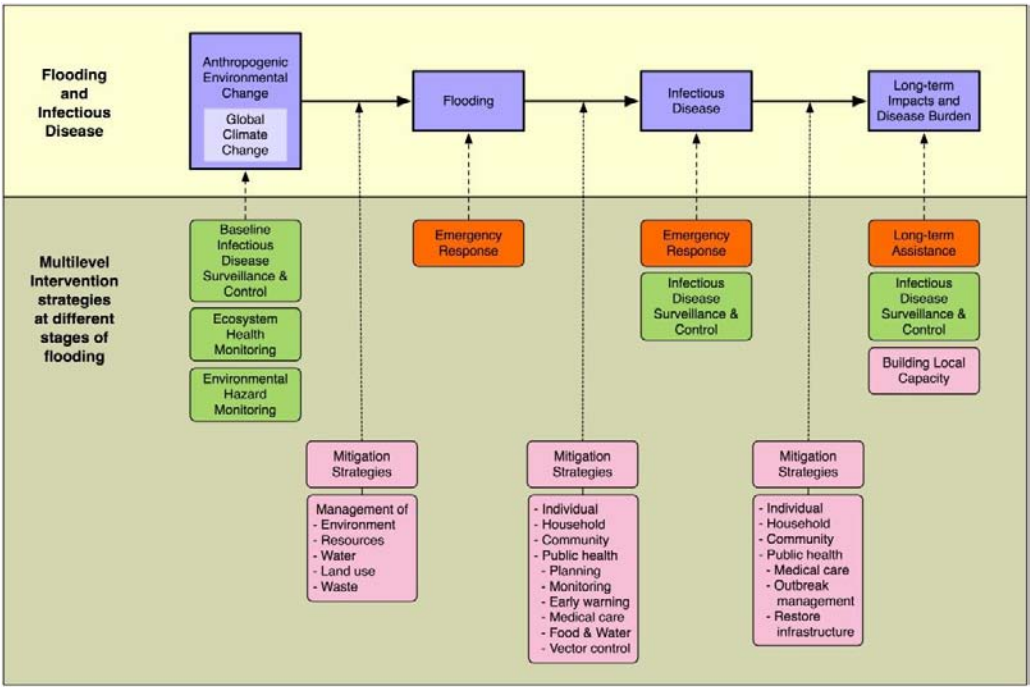

Figure 2. Mitigation strategies aimed at reducing disease burden post-flooding.

At a public health and community level, preventative measures include forecasting of floods, warning systems, evacuation plans, emergency preparedness planning, personnel training, stock piling of supplies such as food and medicines, and ensuring the availability of shelters for residents in high risk areas. Control measures post-disaster include the provision of food and clean drinking water, management of waste and sewage, access to healthcare, mass immunisation programs, vector control, management of environmental hazards, and restoration of public health services. The risk of infections in survivors might also be reduced by community education on general hygiene, and increasing awareness of flood-related infectious diseases and prevention strategies. Protection of homes and prompt rebuilding efforts will also reduce the risk of infectious diseases from overcrowding (35).

Recovery from severe natural disasters can be protracted, and emergency response teams need to consider the requirements for long-term assistance as well as the immediate relief efforts. Potentially useful measures include sustainable environmental and health interventions, and building local capacity for ongoing surveillance, control, and management (8).

Parents, teachers, healthcare workers, and community workers should also be educated about the vulnerability of children post-disaster, and provided with the information and resources to protect them. School-based education programs and evacuation drills for disasters might also empower children themselves, help them cope with dangers at times of disasters, and prepare them for future risks (12).

At a household level, preparation strategies that will reduce their vulnerability to external stresses include stock piling of supplies and food, income diversification, insurance, and asset accumulation. Strategies to protect the home and personal property from flooding include appropriate house design, building on higher ground, ensuring proper drainage, and management of land use around the home. Families should also ensure that they are aware of local post-flood hazards, and respond to public warnings in a timely manner (35).

At a more global level, maintaining healthy ecosystems will reduce not only the risk of natural disasters, but also their consequences such as the emergence and re-emergence of infectious diseases. Protecting our ecosystems will therefore reduce disease risks for the children of tomorrow (2).

As can be seen, there is a wide range and scope of mitigation strategies that can potentially reduce disease burden from flooding. Many of these are time and resource intensive, and further research is required to assess the relative effectiveness of these interventions, both in the acute phase of disasters and in the long-term. Such information is essential for cost-effective allocation of human and financial resources to combat the health risks posed by climate change. New strategies might also be required in order to adapt to changing infectious disease dynamics in a changing climate.

CONCLUSIONS

Knowledge gaps in the epidemiology of infectious diseases post-flooding include the disease burden attributable to infections during the different phases of disasters, long-term health effects of floods, value of early warning systems, effectiveness of current public health interventions, the potential effects of climate change on flooding, and how this will in turn mediate infectious disease risk in different environmental settings, particularly in the most vulnerable groups such as children in rural areas (24).

Long-term surveillance of infectious diseases is vital to our understanding of the transmission dynamics of the wide range of potential pathogens that might wreak havoc after flooding (8). Assessment of disease burden attributable to different infections is essential for evaluating the economic and human cost of infectious diseases, which will inform prioritisation of mitigation strategies. Disease surveillance is therefore crucial for effective management and control of infectious diseases at clinical as well as public health levels. Human health surveillance data and disease outbreaks can also provide early warning signs of ecosystem damage, and be used as indirect bio-indicators of ecosystem health. This information can in turn be used to guide multilevel ecosystem interventions, and prioritise these in an environment of limited public health resources (36).

The development of evidence-based tools and models for monitoring ecosystem health, monitoring environmental hazards, and assessing the cost-effectiveness and sustainability of intervention strategies will be critical for guiding resource allocation for mitigation strategies as well as public health management post-flooding (2).

In order to achieve the above aims, it is essential to improve public health infrastructure, enhance surveillance systems, encourage research on the immediate and long-term health impact of natural disasters, improve our understanding of the environmental drivers of disease emergence, and build capacity to cope with the increasing threats of infectious disease as a result of environmental and climate change.

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Chapter 10

CLIMATE CHANGE EFFECTS ON TREMATODE AND NEMATODE DISEASES AFFECTING CHILDREN IN RURAL AREAS OF DEVELOPING COUNTRIES

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Among climate change impact on human health, the effects on children living in poor rural areas of developing countries pose a series of question marks and risks related to climate-induced modifications of incidence, prevalence, intensity and geographical distribution of infectious diseases. Parasitic diseases are highly susceptible to climatic variables due to their transmission following the life cycle characteristics and links to abiotic and biotic factors of the environment of both parasite causal agents and transmitting invertebrate vectors. Helminthiases, mainly trematodiases and nematodiases, have recently shown to be also susceptible to changes induced by climate change and global warming. In several, as fascioliasis globally and schistosomiasis in Asia, consequences have already been demonstrated, including increases of disease transmission and human infection, as well as geographical spread. In many others, their transmission characteristics, highly dependent on climatic variables, have allowed to predict similar consequences by means of mathematical modelling, remote sensing from space satellites and geographical information system computer methods. The present review offers a baseline on the interaction of climate change and the characteristics of trematodiases and nematodiases known to have a great impact on children. The complexity of climate change variables is analyzed from the point of view of the its expected impact on the different transmission phases of the diseases more susceptible to be modified, including fascioliasis, fasciolopsiasis, gastrodiscoidiasis, schistosomiasis, trichuriasis, ascariasis, visceral larva migrans by *Toxocara*, ancylostomiasis, necatoriasis, cutaneous larva migrans by ancylostomatids, lymphatic filariasis and onchocerciasis. Concluding remarks for future research and immediate action are finally added.

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INTRODUCTION

Within the wide diversity of effects and complex aspects related to climate change, the consequences on human health are among those of most concern. Effects of climate change on health will affect most populations in the next decades and put the lives and wellbeing of billions of people at increased risk. Major threats, both direct and indirect, to global health from climate change are expected through changing patterns of disease, water and food insecurity, vulnerable shelter and human settlements, extreme climatic events, and population growth and migration (1). Large-scale climate fluctuations are linked with changes in the properties and functions of ecosystem. Thus, climatic factors affect ecological processes at different levels, from the performance of individual organisms, to the dynamics of populations and interactions in and between communities, up to the distribution of species. The ecological consequences of climate change in terrestrial and marine ecosystems are expected to be determined by complex cascading effects arising from modifications in both trophic interactions and competitive relationships.

Among climate change effects on health, the Intergovernmental Panel on Climate Change (IPCC) warned that the climate change could affect infectious diseases as early as 1990, when referring to vector-borne diseases (2). Changes in climate factors may affect the distribution or ecological range of infectious diseases, whereas the frequency and magnitude of disease outbreaks may change with weather extremes such as flooding and droughts. Evidence-based biological effects of climate change on living organisms, including pathogens and their vectors, comprise (3): (i) effects on physiology, metabolism or development rate; (ii) effects on distribution; (iii) effects on the timing of life-cycle or life history events; and (iv) adaptation, particularly of the so-called r-strategist organisms. According to the ecological theory on the r and K selection concepts, r strategists are species with short generation times and rapid population growth rates and consequently the most responsive to climate change (4). This is the case of microparasites, including viruses, bacteriae and protozoans, which have been the pathogens more related to infectious disease emergence (5). Moreover, recent evidence indicates that infectious disease agents which are vector-borne in transmission and zoonotic in origin are those whose characteristics are more suitable for climate change impact. It is estimated that 75% of emerging human pathogens are zoonotic (6-8).

Parasitic organisms, both microparasite protozoans and macroparasite helminths and arthropods are known to follow life cycles and transmission characteristics modulated by climate variables since long ago (9). More recently, many studies have emphasized the causal relationship between climate change and parasitic diseases, whether emerging (new infections) or re-emerging (diseases rapidly increasing in either local prevalence and intensities or expanding their geographical distribution) (10,11). However, a very few years ago, helminthiases were noted as infectious diseases scarcely affected by climate change, when compared to diseases caused by microorganisms in general (viruses, bacteriae, rickettsiae, protozoans). A quantitative analysis of the risk of infectious disease emergence allied to the nature of the organisms, their mode of transmission and source, showed that viruses, bacteriae and protozoans are more likely to emerge than macroparasites, e.g. helminths (5). The confirmation about the impact of climate change on helminthiases has been reached only very recently (12), despite a very broad literature on the interactions of helminths with abiotic and biotic factors, including both experimental and field studies.

Although helminths also appear to be affected by climate change, their main difference with microparasites lies on the usually longer life cycles of helminths, with longer generation times, slower population growth rates and longer time period needed for the response in the definitive host to become evident. Within the r/K dichotomy and continuum, helminths are also r-strategists, but appear to be less r than viruses, bacteriae and protozoans (13). Consequently, after a pronounced climate change in a local area, modifications in helminth populations need more time to be obvious or detectable than modifications in microparasite populations. Similarly, the relation of changes in a helminthiasis with climatic factor changes, as extreme events elapsed relatively long time ago, may be overlooked if not concretely searched for. All indicates that this phenomenon has been the reason for previous analyses to conclude that helminthiases do not constitute priority targets in climate change impact studies (14).

Helminthiases have a tremendous importance because of their large impact on human health whether directly in helminth species specific of humans or indirectly in helminth species proper of animals but able to infect humans, as in the case of zoonotic helminthiases. Additionally, several helminthiases are transmitted by invertebrate vectors, such as snails and insects, whose specificity, population dynamics, ecological requirements and behavioural characteristics markedly define transmission patterns and epidemiological scenarios of the vector-borne helminthic diseases in question.

Many helminthiases are, moreover, within the list of the most important infectious diseases in which concerns morbidity and mortality affecting children in developing countries. This scenario is worse in rural areas of low-income countries, where health infrastructures and minimum care, mainly diagnostic and treatment possibilities, are usually far from those available in urban areas. One wonders which will be the consequences of climate change on the aforementioned helminthiases affecting children in those rural, poor areas where civilisation, man-made infrastructures and appropriate public health systems are not there to deal with adverse outcomes. The present review analyzes the human helminthiases presenting transmission characteristics most suitable to be affected by climate change, by focusing on trematodiases and nematodiases of well-known impact on children inhabiting rural areas of developing countries. The aim is to provide a baseline for future action on crucial parasitic diseases pronouncedly affecting rural child health in a climate-changing world.

HELMINTH TRANSMISSION STRATEGIES AND CLIMATE CHANGE

According to the life-cycle pattern of each helminth species, climate variables are able to affect prevalences, intensities and geographical distribution of helminths both directly influencing on free-living larval stages, as well as indirectly influencing on mainly invertebrate but also vertebrate hosts of their parasitic stages (12).

Host (or vector) specificity characteristics of each helminth species are crucial. Helminths showing a strict host specificity, that is, only able to develop within a concrete host species, or even concrete host geographical strain, will be very dependent on the influences of climate change on the host population. On the contrary, helminths showing a less marked host specificity, that is, able to develop within different host species, or even phylogenetically distant species, have the possibility to buffer the influence of climate change more or less depending from the different adaptative capacities of the different host species to a given climate modification. However, a wider definitive host spectrum may also play favouring disease transmission speed and modifying disease characteristics as prevalences, intensities and geographical distribution in a faster way, so that climate change impact becomes easier to be detected and measured in a shorter time period. This is the case of several zoonoses, well-known examples of emergence or re-emergence in the last two decades (15,16) and markedly related to climate variability (17), and, within helminthic diseases, of fascioliasis worldwide and schistosomiasis japonica in Asia (14), in which the causal agents are characterized by a very low specificity at definitive host level and, hence, with a very wide animal reservoir species spectrum (see below).

Helminth species affecting humans and domestic animals belong to four systematic groups: digenetic trematodes or flukes, cestodes or tapeworms, nematodes or roundworms and acanthocephalans or thorny-headed worms. These metazoan parasites present very different transmission patterns, ecological requirements and spreading strategies according to the different helminth groups. Their dependence on abiotic and biotic factors is related to their free living stages, and their environment-host population interactions (12). Among the numerous environmental modifications giving rise to changes in helminth infections, climate variables appear as those showing a greater influence (9).

Trematodes and nematodes are the helminth groups including parasite species whose life cycle and transmission characteristics are more susceptible to climate change. Among both groups, there are moreover several species able to infect humans and cause diseases that affect mainly children in rural areas of developing countries. They are, therefore, the main purpose of the present analysis and are treated appropriately below.

Cestodes follow life cycles which are less influenced by climatic conditions and cause diseases not particularly problematic in children as to be considered within helminthiases whose morbidity affects their development. Additionally, although studies on emergence/re-emergence suggest that climate change may also have an impact on cestodiases, the only tapeworm disease in which climate change has been found to influence so far is alveococcosis or multilocular hidatidosis by *Echinococcus multilocularis* (12), a disease causing high mortality in humans but which does not appear to be especially focused in children. Another cestode disease frequently affecting children in developping countries and in which climate factors are known to have an influence is hymenolepiasis by *Hymenolepis nana*. However, its low pathogenicity, lack of recognized underdeveloping impact and the absence of field studies hightherto demonstrating or suggesting climate change effects on hymenolepiasis, does not indicate that this disease should be included in the list, at least for the moment.

Acanthocephalans are less important in public health, although they may be very pathogenic. Their very rare infection in humans does not merit a special analysis from the point of view of climate change.

MAIN CLIMATE FACTORS INFLUENCING HELMINTHIASES

Analyses on the influence of climatic factors on the transmission and spreading of helminth species have been very numerous since long ago, both experimentally on biological models adapted to laboratory conditions and under natural conditions in field studies. However, this kind of studies have been focused on climate change only very recently, so that the literature on the modulation of helminth parasitism by changing climatic conditions is still scarce (12,14).

It must be highlighted that generalizations about effects of climate change on helminths cannot be made. On one side, their broad heterogeneous complexity of life-cycle patterns include completely antagonistic strategies, so that given changes of concrete climate variables may give rise to modifications of helminthiasis trends following 'opposite' directions even in the same area, that is, increasing the transmission of a given helminth but decreasing the one of another helminth species, and reducing the geographical distribution of a given helminthiasis but expanding that of another helminth. Moreover, the influence of a given climatic factor might be increasing transmission when analysed at a given level but show an opposite consequence when considering another level of the helminth life-cycle, so that counteracting effects may finally give rise to almost no change or no change at all in the transmission.

Additionally, climate changes do not appear to be spatially uniform, so that climate change may influence the same helminthiasis in different directions or with different degrees depending on the geographical area in question. Interestingly also, areas predicted to be the most affected by climate change are those near the current edges of disease's global distribution (i.e., geographical borders, highland areas) (18).

Temperature increases the helminth development rate. Infection levels and the dynamics of helminth systems are subject to the impact of long term increases in temperature. From the host perspective, if they breed earlier and for longer due to long-term higher temperatures, this will result in the production of more susceptible young individuals and this will lead to an increase in transmission. From the helminth perspective, an increase in the duration and average temperature of the summer season will also increase the window of transmission and development rate of infective stages resulting in increased transmission (19). As a consequence, global warming will lead to increased levels of helminth parasitism.

Modifications of precipitation rates and changes in rainfall may alter humidity giving rise to whether wetter or dryer conditions in given areas. Such changes will greatly influence the survival range, seasonality and viability of many free-living stages of helminths (eggs, soil larvae), but also those developing in intermediate hosts as snails, insect vectors and even small vertebrates, both exothermic and endothermic. Cloudiness and air pollution interact with sunlight radiation, which is more or less harmful to the exogenous stages of helminths, but may play in an opposite way for given vectors as planorbid and lymnaeid snails which mainly feed on freshwater algae.

Moreover, influences on helminth diseases of changes of each one of these climatic variables cannot be analyzed independently, due to interaction effects. Interactions between temperature and the aforementioned water-related climate variables will give rise to changes in freeze-thaw cycles, modifications of freshwater bodies, or changes in water velocity, so that droughts, floods, and run-offs will increase in frequency. Climatic cascading effects are increasingly being detected, as for instance in extreme latitudes. Such climate change combinations significantly impact ecosystems and the diversity and abundance of the inhabiting invertebrate communities (20).

TREMATODIASES

Trematodes follow an heteroxenous life cycle in which the first intermediate host is a specific mollusc. In trematodes following a two-host life cycle, the vertebrate definitive host becomes infected whether through the skin by the snail-released larval stage of cercaria (in schistosomatids), or by ingestion of the metacercaria attached to any carrying substratum (e.g., freshwater plants, in fasciolids). In three-host life-cycles, the vertebrate host becomes infected by ingesting the second intermediate host, usually an invertebrate (molluscs, insects, crustaceans) or an exothermic vertebrate (fishes, frogs, reptiles). Climate conditions whether directly influence free larval stages (eggs faecally shed by the vertebrate host, miracidium development inside the egg, snail-released cercariae, and non-parasitic metacercariae) or indirectly the parasitic larval stages (sporocysts, rediae, cercariae in the snail; metacercariae in invertebrates) (14).

Climate change has been shown to affect trematode transmission at different levels of the parasite's life cycle, including aspects as (i) cercarial output, (ii) cercarial production variability, (iii) magnitude of cercarial production, cercarial size and snail host size, (iv) cercarial quality, (v) duration of cercarial production increase and host mortality, and (vi) latitude. The common scenario comprises an increase of a few temperature degrees leading to marked increases in cercarial emergence from snail vectors and consequently in disease transmission (14,21).

Although the aforementioned important global-warming-induced impact affects all trematodiases, data available so far suggests that flukes that follow a two-host life cycle and whose epidemiological characteristics are strongly marked by their zoonotic origin are the trematodiases showing a higher, or at least faster detectable, climate change impact. Changes in prevalences, intensities and geographical distribution at definitive host level, including both human and other mammal host infection, are more directly influenced in these cases due to the absence of any intermediate host population buffering this effect in between snail vector and definitive host. Moreover, the existence of animal reservoir host species additional to the human host allows to enhance this transmission increase effect in a faster way. This explains why, within plant-borne trematodiases, the liver fascioliases by *F hepatica* and *F gigantica* using a large spectrum of herbivorous and omnivorous mammal hosts (see figure 1C,D) are more affected than the intestinal fasciolopsiasis and gastrodiscoidiasis which only use the pig as animal reservoir host. Similarly, the less specific schistosomiasis by *Schistosoma japonicum* using a large spectrum of mammal reservoir hosts (figure 1E) appears to be more affected than the almost strictly human-specific schistosomiases by *S mansoni* and *S haematobium*. Another curious zoonotic, two-host life cycle trematode disease, cercarial dermatitis or swimmer's itch caused by bird schistosomatid flukes, has also proved to be affected by climate change, although this disease does not target especially on children and does not pose problems in developing countries, but only in northern mild or cold latitudes of Europe and North America (see table 1) (12,14).

Figure. 1. A, B) Amphibious snail vectors of fascioliasis are highly susceptible to climate change, as is the case of Galba truncatula at 3900 m high altitude in the Nothern Bolivian Altiplano (A) and Lymnaea viridis throughout the lowlands of Vietnam (B). C, D, E) Less specific trematodes using a wide spectrum of animal reservoir hosts evidence climate change effects faster: according to the traditions of Aymara inhabitants of the Nothern Bolivian Altiplano high endemic area, young children are in charge for the management of livestock (C, D); in the Far East, the combination of livestock with field cultures needing intensive irrigation (see rice fields in the background) facilitates the transmission of schistosomiasis by Schistosoma japonicum (E). F) How to tell children in Africa not to bath to avoid infection when the air temperature is around 40 °C? G) Despite efforts in providing electricity (see pylon in the background) and water piping (see pipe crossing canal), women and girls still wash with feet inside water according to centenary traditions in Egypt, thus exposing themselves to schistosomiasis infection. H, I) Consumable vegetables and promiscuous outdoor defaecation (see bottom right) are typical links in soil-transmitted nematodiases: uncontrolled plant markets are numerous in Asian countries (H); rain and floods contribute to the spread of nematode eggs expelled with stools throughout the environment (I).

Table 1. Climate change effects on different trematodiases and nematodiases affecting children. + = low impact; ++ = middle impact; +++ = high impact; ++++ = very high impact. --- = does not apply.

Disease causal agent	Effects on free living stages of the parasite	Effects on larval development inside vector	Effects on vector host	Effects on intermediate (or paratenic) host	Effects on zoonotic transmission	Impact on children	Impact on human development
TREMATODIASES:							
Fasciola hepatica, F. gigantica	++++	++++	++++	---	++++	++++	++++
Clonorchis sinensis	++	++++	+++	++	++	++	+++
Opisthorchis viverrini, O. felineus	++	++++	+++	++	++	++	++++
Paragonimus spp.	++	++++	+++	++	++	+	+++
Fasciolopsis buski	++++	++++	+++	---	+	+++	+++
Gastrodiscoides hominis	++++	++++	+++	---	+	+++	+++
S. mansoni, S. haematobium	++++	++++	+++	---	---	++++	++++
Schistosoma japonicum	++++	++++	++++	---	++++	++++	++++
Cercarial dermatitis	++++	++++	+++	---	++++	+	+
NEMATODIASES:							
Trichuris trichiura	+++	---	---	---	---	++++	++++
Ascaris lumbricoides	+++	---	---	---	+	++++	+++
Toxocara canis, T. cati (VLM)	+++	---	---	--- (+)	+++	+++	+
A. duodenale, N. americanus	++++	---	---	---	---	++++	++++
Cutaneous larva migrans	++++	---	---	--- (+)	+++	+++	+
W. bancrofti, B. malayi	---	++++	++++	---	---	++	++++
Onchocerca volvulus	---	++++	++++	---	---	++	++++
Loa loa	---	++++	+++	---	---	+	+
Dirofilaria immitis, D. repens	---	++++	++++	---	+++	+	+
Enterobius vermicularis, E. gregorii	+++	---	---	---	---	++++	+
Strongyloides stercoralis	++++	---	---	---	---	+++	++
Angiostrongylus cantonensis	++	++++	++++	++	++++	+	+
Angiostrongylus (M.) costaricensis	++	++++	++++	++	++++	+	+

Among the rest of important trematodiases of humans, the Asian food-borne hepatic clonorchiasis by *Clonorchis sinensis* and opisthorchiases by *Opisthorchis viverrini* and *O felineus* are dependent from climate variables (22-24) and will undoubtedly be affected by global warming and also water-dependent factors modifying water collections in the field, although their use of a freshwater fish carrying the infective stage of metacercaria, despite its dependence from abiotic factors (25), may not allow to transfer the climate change impact at snail vector level to definitive host infection, including human disease, so evidently. A similar observation may be made with the food-borne, pulmonary paragonimiases caused by several species of *Paragonimus* mainly in Asia, but also in Africa and the Americas (26). Moreover, none of these food-borne trematodiases focuses especially on children, althouh *C sinensis* in some endemic areas of China and *O felineus* in Russia and Ukraine may reach relatively high prevalences in children locally (22). These food-borne trematodiases have been mentioned to emerge in recent times (27), although nothing indicates that a climate change impact may be in the background of these emergences in spite of their zoonotic origin, at least so far (see table 1).

FASCIOLIASIS

Fascioliasis is a highly pathogenic disease caused by *Fasciola hepatica*, present in Europe, Africa, Asia, the Americas and Oceania, and *F gigantica*, mainly distributed in Africa and Asia. This disease is typically rural, has a great spreading power thanks to the large colonization capacities of its causal agents and vector species, and is at present emerging or re-emerging in many countries, including both prevalence and intensity increases and geographical expansion. Today, fascioliasis is the vector-borne disease presenting the widest latitudinal, longitudinal and altitudinal distribution known. Human cases have been increasing in 51 countries of the five continents, with estimates of up to 17 million people affected or even higher depending from the hitherto unknown situations in many countries, mainly of Asia and Africa (28-30). Different human endemic and epidemic situations with long-term, high morbidity effects have been described. Children and females appear to be the most affected in human high endemic areas (31,32).

The two-host life cycle of both fasciolids is similar. It comprises four phases (22): A) a very wide spectrum of herbivorous (sheep, cattle, goats, equines, etc.) and omnivorous (pigs, humans, etc.) mammals act as definitive host; infected by ingestion of metacercariae with vegetables or drinking water, they harbour fluke adults in biliary canals and gall bladder; eggs reach the external milieu with faeces; in man, the long chronicity problem in endemic areas is due to the fluke life span of up to 13.5 years; B) the transit between mammal and snail hosts includes the long resistance phase of egg and short active phase of miracidium in freshwater of appropriate physico-chemical characteristics (mainly temperature of 15-25° C); C) vectors are specific freshwater lymnaeid snail species; the intramolluscan larval development finishes with the shedding of cercariae into water; the prepatent period (38-86 days) is dependent on temperature, higher temperatures reducing the period; D) the transit between snail and mammal host includes the short swimming phase of cercaria and the long resistance phase of metacercaria attached to freshwater plants or water surface; the shedding process takes place between 9° and 26° C, independently of light or darkness; metacercarial cysts become infective within 24 hours and remain viable for months, even more than a year. Thus, liver fluke development is very dependent of the environmental characteristics according to phases B, C and D, and markedly influenceable by human activities at phase A. The large heterogeneity of transmission patterns and epidemiological scenarios seems to be related to different lymnaeid vector species (30,32,33).

Fascioliasis fulfills all adequate requirements for an helminthic disease to be highly and relatively rapidly (in comparison to other helminthiases) affected by climate change: (i) two host life cycle without any intermediate host between snail vector and mammal host; (ii) very dependent on climatic variables in most of its life cycle; (iii) amphibious snail vectors very dependent on climatic conditions (see figure 1 A, B); (iv) high zoonotic component due to the very low specificity at mammal host level (see figure 1 C, D). This is why fascioliasis has always been the model most used to illustrate helminth-climate interactions (9), as well as to develop climate forecasting methods and evaluate their usefulness.

The incidence of fascioliasis has been related to air temperature, rainfall and/or potential evapotranspiration. There are climatic fascioliasis forecast indices which are calculated with different equations which take into account variations in these climatic factors (34-37). Several have been successfully applied to animal fascioliasis in different areas of Europe, Africa and the USA (38). Recently, they were also successfully applied to human fascioliasis in Bolivian highlands, after introducing a modification in the aridity calculation deduced from climatediagrams in the way to adapt the indices to high altitude and low latitude (38). The validation was performed by using data about human and animal fascioliasis as well as lymnaeid vector distribution and peculiar physiographic characteristics of the very high altitude covering the whole 3800-4100 m altitude human hyperendemic area of the Northern Altiplano (39). The values of one index allowed even to classify the degree of disease transmission into low, moderate and high risk areas. Worth noting is that the only Altiplanic lymnaeid vector snail species appears to be almost exclusively linked to permanent water bodies, because of the high altitudinal evapotranspiration leading temporal water bodies to quickly disappear thus unabling lymnaeids to adapt and develop (39). This explains why the transmission on the Altiplano takes place throughout the year, opposite to the typical fascioliasis seasonality in northern hemisphere countries.

In other regions, different factors have been used in the models developed. Bayesian hierarchical models of the spatial distribution of bovine fascioliasis in Victoria, Australia, were developed using data of liver fluke infection in cattle together with environmental aspects. Rainfall was found to have an inconsistent relationship with the fluke prevalence data, whereas irrigation was the variable that best described the observed distribution of the disease (40).

A more complex suite of environmental factors related to fascioliasis and available from space satellites may be used for forecasting by means of Remote Sensing (RS) and Geographic Information System (GIS) methods (41): (i) temperature, air, soil and surface water (diurnal temperature maximum and minimum, diurnal temperature difference, sea/water/land surface temperature), (ii) water, including soil moisture, standing water and atmospheric water vapor; (iii) condition of vegetation canopy over the earth, (iv) structure and dynamics of the lower atmosphere plus composition and dimensions of airborne particles (aerosols) contained, and (v) topography and mineralogy, i.e. terrain relief and bedrock/soil types. In RS-GIS for animal fascioliasis, surface hydrology, vegetation indices and temperature data based on previous knowledge have proved to be very useful (see review in

42). Annual normalized difference vegetation index (NDVI) values together with a climatic index were initially proposed for human fascioliasis in Chile (43) and later successfully applied and validated for the Northern Bolivian Altiplano high human hyperendemic area (44). The prediction capacity of the RS map appeared to be higher than that from forecast indices based only on climatic data (38). A GIS forecast model to conduct an epidemiological analysis of human and animal fasciolosis in the central part of the Andes was proposed (45). NDVI data maps represent a step further in the way to reach a GIS based on various parameters which could accurately fit real epidemiological and transmission situations of fascioliasis in high altitude endemic areas in Andean countries (46). More recently, levels of vegetation have been also reported as a positive predictor of *F hepatica* in Switzerland (47).

Data layers of environmental variables including inundation, elevation, slope and distance from river were used in a GIS model for mapping risk of fascioliasis in Cambodia, where a combination of draught animals and the cultivation of irrigated rice in the periphery of flooded areas provide a suitable habitat for lymnaeid vectors and their infection. Interestingly, temperature was excluded from the model because it fluctuates little during the year in Cambodia and persists in the range favourable to snails. Similarly, rainfall was also excluded because annual floods were associated with melting snow rather than rainfall (48,49).

The strong dependence of fascioliasis from weather factors indicate that climate change may have a marked influence on this disease. In South America, global warming effects have already been described in the Northern Bolivian Altiplano high human hyperendemic area. Fast shrinkage of glaciers and perpetual snows are expected to modify the hydrological characteristics of the endemic area, with consequences on lymnaeid vector distribution and fascioliasis transmission (12,14). The El Niño-Southern Oscillation (ENSO) phenomenon and associated precipitation modifications, drought and floods are expected to modify fascioliasis transmission in Andean countries as Ecuador, Peru and Bolivia. Animal fascioliasis outbreaks were already detected in Ecuador after the great climatic irregularities taken place after the 1997/98 ENSO phenomenon (12,14). The typical extreme climatic events in the Caribbean region, as for instance hurricanes, are also capable to give rise to human and animal fascioliasis outbreaks due to the pronounced r-strategist characteristics of the widely distributed snail vector *Lymnaea cubensis*. In Cuba, several human outbreaks have been described which characterize the Caribbean transmission pattern and epidemiological scenario (32). The increasing frequency of such climatic events in recent years may increase the frequency of fascioliasis outbreaks.

In Europe, the appearance of human outbreaks after heavy rainfall in the previous year or season has been reported repeatedly (22). Modifications of raining rates including temporary concentration of rainfall and consequent floods may influence fascioliasis transmission in the areas affected and cause epidemics. Recently, global warming has been noted as the cause of increased animal fascioliasis in UK (50-53) and France (54).

In Africa and Asia, predicting future scenarios of fascioliasis related to climate change becomes more difficult due to the overlap of the distributions of *F hepatica* and *F gigantica*, together with the widespead presence of hybrid intermediate forms which may not necessarily follow known thresholds for the pure species, as e.g. minimum temperature thresholds for larval development of 10 °C for F. hepatica and 16 °C for F. gigantica (14). The Nile Delta in Egypt, Gilan province in northern Iran, and Vietnam are examples of endemic areas where forecasting initiatives will be jeopardized by the genetic complexity of the fasciolids (14).

Forecast and risk models made for areas where both fasciolid species overlap and hybrids are present, such as Ethiopia (55), east Africa (36) and Cambodia (48, 49) should be re-assessed in the future once development thresholds of the local hybrid forms become known after appropriate experimental studies.

FASCIOLOPSIASIS

The Giant Asian intestinal fluke *Fasciolopsis buski* is one of the largest digeneans infecting humans. It inhabits the duodenum and jejunum in light infections and also much of the intestinal tract, including the stomach, in moderate and heavy infections (56). Pigs are the only animal reservoir of any significance (28,29). Fasciolopsiasis affects several million people in Asia, widely expanded in central and south China, Hong Kong, Taiwan, Bangladesh, India, Vietnam, Laos, Cambodia, Thailand, Kampuchea, Singapore, Burma, Malaysia, the Philippines, and Indonesia (28,29). In humans, mortality has been reported in children with heavy infections in India, China, and Thailand, and massive infections are responsible for clinical symptoms, intestinal disturbances, malnutrition, edema, and malabsorption (57).

In the endemic areas, the disease is underreported and is most prevalent in remote rural places and semi-urban areas. Fasciolopsiasis is most prevalent in school-age children (see review in 28), in which the number of worms per child can exceed 800 (58). Prevalences reported in children ranged from 57% in mainland China to 25% in Taiwan and from 60% in India and 50% in Bangladesh to 10% in Thailand (28,29).

The transmission of fasciolopsiasis follows the same pattern as in fascioliasis. The life cycle phases which develop in water are extremely susceptible to climate. Temperature and water-related climate variables greatly influence the embryonation of eggs in freshwater. The miracidium development period is 16-77 days, with a mean of 22 days, the optimum being 27-30 °C of water temperature and 6.5-7.2 as pH range (28).

The small planorbid snail vectors involved are extremely sensitive to dessication, their survival limit out of water at 25 °C and 50% humidity being 25 hours (59). Exposure of 2 hours to drying usually kills them, but they are able to live for some time in slightly moist mud. Moreover, the parasite larval development within the snail vector is markedly dependent on abiotic factors such as temperature. Incubation periods recorded were 46-59 days at 22-24 °C, and longer, of 85-100 days at 18-22 °C (59). Additionally, cercarial emergence from the snails is dependent on light, cercariae being strongly phototactic, with a great variation having been noticed in the daily emergence patterns of cercariae (60).

The disease occurs focally, is wide-spread and is linked to freshwater habitats with stagnant or slow moving waters (58,61). The disease is therefore susceptible to climatic changes in precipitation rates as well as rainfall and extreme events as floods and drought which may modify freshwater bodies and water velocity.

It appears to follow a seasonality, with a peak between June and September declining thereafter to a low level during winter and early spring (November-March), being absent during January and February, at least in a humid subtropic hilly city of north-east India where rearing of pigs is a common household practice (62). A local climate change implying a modification of the current seasonality, by enlarging the yearly transmission window, would pronouncedly affect the epidemiological characteristics of fasciolopsiasis in the area, with increase in prevalences, intensities and geographical spread of infection both in humans and pigs.

In endemic areas, the disease appears associated with common social and agricultural practices and aggravated by poverty, malnutrition, poor sanitation, other helminthiases, declining economic conditions and an explosively growing, inspection-lacking free-food market (58,61,63). Differences of incidence are due to factors such as economic status, educational background, standard of health and way of life (28,29).

Control programs focus on school-aged children with large community therapy initiatives (63), including educational efforts directed primarily toward school-age children because they are less entrenched in their food and eating habits, behaviour, and customs (61). Unfortunately, despite control programs implemented and sustained in the communities, fasciolopsiasis still remains a public health problem in endemic areas (63). And in areas where it was thought to be fully controlled, there are reports of a re-emerging infection in recent years (64,65).

GASTRODISCOIDIASIS

The trematode *Gastrodiscoides hominis* infects the caecum and colon of both pig and man (66). The pig is the normal host and only important reservoir, sporadically infected mammals (mainly wild boars) and locally infected rats being without broad epidemiological implications (28,67). It has a large distribution in the Palaearctic Region mostly overlapping fasciolopsiasis, including India, Pakistan, Burma, Thailand, Vietnam, Philippines, China, Kazakstan and the Volga Delta in Russia (57,66,68,69). Its records in Africa need confirmation (28,67).

Infection by this trematode species causes illness in a large number of persons, and deaths among untreated patients, especially children, have been attributed to this infection (66). In human infection, a picture similar to that detected in pigs might be expected (28,67).

This fluke follows a diheteroxenous life cycle similar to those of *F hepatica*, *F gigantica* and *F buski*. Eggs when laid include an embryo in a very early stage of segmentation. The miracidium appears fully mature on day 9 at a temperature of 24-33 °C. Hatching takes place between days 9 and 14 depending from temperature. Higher temperatures appeared to be detrimental for miracidium development. A longer maturation period of 4 weeks was required in April-May. Longer periods of up to 3 months for hatching have also been described (28, 67).

The tiny freshwater planorbid snail *Helicorbis coenosus* (= *Segmentina coenosus*) is the only vector species known. In this snail, the prepatent period ranges between 28 and 152 days, this variation depending on the seasonal variations of temperature, i.e. 51 days at a mean temperature of 24 °C (variation 20-30 °C) and 74 days at 22 °C (variation 17-27 °C). This period is shortest in summer and longest in winter. The longevity of the snails varies from 10 to 147 days after the infection becomes patent, and the snails shed cercariae intermittently for 6-40 days. Positive snails stop shedding when it becomes cold (28, 67).

Cercarial emergence takes place in morning hours. The free swimming life of cercariae varies from 1 hour to more than 24 hours, at the end of which it encysts. Encystation generally takes place on the bottom. A few of them encyst on the shell of the snail host or any other substrate available. Human contamination may occur when encysted metacercariae are swallowed with tainted vegetation (aquatic plants) or with animal products, such as raw or undercooked crustaceans, squid, molluscs, or amphibians (57, 69).

The prevalence in pigs is of great epidemiological significance. In endemic areas, the molluscan vector appears to abound in the water reservoirs around the pigsties (66). In surveys of pigs in north-east India, gastrodiscoidiasis showed a seasonal occurrence trend similar to that of fasciolopsiasis. Their prevalence rose to a peak during the months from June to September, declining thereafter to a low level during winter and early spring (November-March). The infection by *G hominis* was not present during the first 3 months of the year (62).

However, high infection rates have sometimes also been detected in humans in areas where pigs were very scarce, as the 41% prevalence and high individual intensities detected in mainly children in northern India. These results suggested that the infection was maintained in the human population without participation of pigs (28,67).

Summing up, climate change may affect gastrodiscoidiasis in a way similar to fasciolopsiasis, due to the similar life cycle, transmission characteristics, identical animal reservoir species, similar latitudes and overlapping geographical distribution.

Similarly as in fasciolopsiasis, besides treatment and educational measures, methods in control campaigns should include (i) prevention of human infection; (ii) efforts at human level to cut disease dissemination by humans; (iii) control at pig reservoir level; and (iv) efforts at snail vector level. To prevent human infection, the most practical method is to avoid eating raw, water-derived food. Unfortunately, the reality shows how difficult it is to change century-old traditions and therefore the importance of educational efforts at the level of school-age children (28,67).

SCHISTOSOMIASIS

Schistosomiasis or bilharziasis is caused by trematode species infecting the circulatory system of humans, mainly by three species of *Schistosoma*, *S mansoni* in Africa, the Caribbean and South America, *S haematobium* in Africa, and *S japonicum* in Asia. Four other species affect humans only sporadicaly or in more restricted areas, as *S. intercalatum* and *S. guineensis* in tropical Africa, and *S mekongi* and *S malayensis* in South East Asia. This disease is one of the most important human helminthiases due to its very high morbidity (70). Only in sub-Saharan Africa, the 192 million cases represent that schistosomiasis is the second most important after hookworm, accounting for 93% of the world's number of cases of schistosomiasis and possibly associated with increased horizontal transmission of HIV/AIDS (71).

Schistosomiasis was the first trematodiasis to be included among the diseases able to increase both its local infection and geographic expansion with climate change, mainly with global warming (6,72,73). This is in part related to the peculiarity of the larval development of schistosomes within their snail vectors, including an infinite cercarial production capacity related to larval stage replication processes (74).

There are different environmental factors that impact on the distribution of schistosomiasis. Temperature, water body type, rainfall, water velocity and altitude can all have a significant effect on the schistosome life-cycle and survival of the intermediate snail host (75). Climatic changes are likely to affect the known geographical distribution of freshwater snails, such as *Biomphalaria* species, the vector hosts of African schistosome species transmissible to humans (76).

However, up to the present, only schistosomiasis by *S japonicum* in Asia has shown to be affected by climate change (14). In China, for instance, schistosomiasis has re-emerged in mountainous and hilly regions in Sichuan, where it had been controlled previously by intensive interventions (77). The resurgence of *S japonicum* infection in the past few years is taking place despite 50-year intensive control activities targeted against the amphibious snail vector, *Oncomelania hupensis*, and large-scale chemotherapy campaigns using praziquantel.

Results of a study on a time-series from 1972 to 2002 for 39 counties of eastern China, where *S japonicum* is endemic, showed that temperature increased over the past 30 years in all observing stations. Prediction methods showed temperature increases for the entire area studied, with an increase from north to south, and suggested an impact on the frequency and transmission dynamics of schistosomiasis japonica (78,79).

Moreover, environmental changes resulting from global warming but also from the Three Gorges dam were expected to result in a widening of the habitat of *O hupensis*. Unfortunately, predicting the climate-change-induced geographical spread of this vector was not as simple as initially expected, due to the complexity and heterogeneity of the snail species involved. The considerable variation of snail habitats, from mountainous habitats in the west to flood plain habitats in the east, proved to be associated with different subspecies of *O hupensis* (80). Thus, the existence of different *O hupensis* vector subspecies in the region hampered the predictive models of the spatial distribution of schistosomiasis. Additionally, the prediction of schistosomiasis risk to identify the habitats of *O hupensis* in mountainous regions was complicated by the occurrence of seasonal flooding (81). This is a good example about how global warming influencing both (i) the development of the parasite larval stages and consequently the transmision of the disease and (ii) the spread of the snail vectors of the schistosome and consequently the geographical distribution of the disease, might jeopardize a long-term successful control program (82-85).

Whereas climate change has already shown to influence a pronouncedly zoonotic schistosomiasis in northern temperate latitudes in Asia (figure 1 E), the question is still posed about whether climate change may modify, and up to which level, non-zoonotic schistosomiases by *S mansoni* and *S haematobium* in tropical and subtropical latitudes of Africa (see figure 1 F,G) (or additionally the Americas in the case of *S mansoni*). Schistosomiasis has re-emerged many times in Africa in recent times. Anyway, in all these situations re-emergence was related to global change instead of to climate change, that is, in response to environmental and sociopolitical changes such as hydrological changes, e.g. construction of dams, irrigation canals, reservoirs, etc., that establish suitable new environments for the intermediate host snails that transmit the parasites (11).

Mapping schistosomiasis in Africa has been a priority since long ago (86). Computer modelling has been applied to schistosomiasis in different African countries, such as Egypt (87) and South Africa (88), although focused on the geographical characterization rather than on the prevalence or intensity of infections. Only few attempts have been made thus far to predict changes in the frequency and transmission dynamics of schistosomiasis due to climate change in Africa (89,90). The lack of long-term, high-quality datasets, among other reasons, have been argued to explain the discrepancy reported in given studies which did even came to different conclusions regarding the extent of schistosomiasis transmission under the scenario of a warmer climate (89,90).

The marked differences between Africa and Asia with regard to the ecological characteristics of the respective freshwater snail vectors shall also be taken into account. The vectors of *S mansoni* and *S haematobium* are species of *Biomphalaria* and *Bulinus*, both pronouncedly more aquatic than *O hupensis*. The latter Asian snail is of amphibious behaviour, similar to that typical of lymnaeid snails transmitting the liver fluke *F hepatica* and snails which have already proved to be susceptible to climate modifications. Thus, schistosomiases in Africa and the Americas are a priori susceptible to be influenced by climate change effects, although climate-change-induced modifications on schistosomiases in Africa and the Americas may not be similar to those seen in Asia.

Furthermore, in Africa new strains of schistosomes are indeed progressively detected through natural hybridizations between different species of schistosomes from humans (91), from humans and rodents (92), and from humans and cattle (93). The question immediately rises about which will be the development thresholds of these hybrid forms with regard to the different climatic variables. This means that thresholds assessed for African human pure schistosome species time ago may not be further extrapolated to the schistosome hybrid forms, in a way similar to the same development question posed by fasciolid hybrids (30).

NEMATODIASES

Nematodes present from very simple up to complex life cycles. Trichurids (*Trichuris*) and ascarids (*Ascaris*, *Toxocara*) are monoxenous with a definitive mammal host and the egg as only free living stage depending on environmental factors (pseudoeoh-elminths).Ancylostomatids and *Strongyloides* are also monoxenous but present active free-living larval stages highly dependent from abiotic factors (geohelminths) (see figure 1 H, I). Other nematodes present a two-host life-cycle including vector-borne parasites transmitted by biting dipteran insects (filarids and *Onchocerca*). Diheteroxenous protostrongylidae are transmitted by strongly climate-dependent snails. Thus, nematodiases are amongst the helminthiases which will presumably be more afected by climate change (see table 1).

Many nematodiases strongly dependent on climate characteristics, which mainly affect children and which represent a serious handicap for the development of rural communities in developing countries are analyzed in the following. There are other nematodiases, however, which are also affected by climate variables and mainly infect children but whose impact on child development is low, as strongyloidiasis or anguillulosis by *Strongyloides stercoralis* and oxyuriasis or enterobiasis by the ageohelminth species *Enterobius vermicularis* and *E gregorii*. Additionally, both the snail-borne angiostrongyliasis or eosinophilic meningoencephalitis by *Angiostrongylus cantonensis* and the snail-borne abdominal angiostrongyliasis by *Angiostrongylus* (*Morerastrongylus*) *costaricensis*, as well as the mosquito-borne dirofilariases by *Dirofilaria immitis* and *D repens*, are nematodiases which have already been verified to be affected by climate change (12), but children are not particularly infected by these diseases. Strongyloidiasis and oxyuriasis are human-specific diseases, whereas angiostrongyliases and dirofilariases are zoonotic, with rats and dogs and cats as main definitive animal hosts, respectively (see table 1).

TRICHURIASIS, ASCARIASIS AND TOXOCARIASIS

The two pseudogeohelminth species *Trichuris trichiura* (whipworm) and *Ascaris lumbricoides* (roundworm) are soil-transmitted by eggs and mainly distributed in tropical and subtropical regions of the developing world where adequate water and sanitation are lacking. The greatest numbers of infections occur in sub-Saharan Africa, East Asia, China, India and South America. Recent estimates suggest that *T trichiura* infects 795 million people and *A. lumbricoides* 1221 million (94).

The development of the adult stage in the human host is similar in the two species, with an adult life span of 1-2 years and a basic reproduction number R_0 (= average number of female offspring produced by one adult female parasite that attains reproductive maturity, in the absence of density dependent constraints) with values of 4-6 for *T trichiura* and somewhat lower, of 1-5, for *A lumbricoides* (95). Considering that the nematode adult life inside the host is in fact a refuge from the external environment, *T trichiura* and *A lumbricoides* are protected from outside temperatures only throughout a 1-2 year period, which means that the chances of their transmission stages to be deposited and develop in suitable thermal conditions are less increased than, for instance, in hookworms whose adult stage life expectancy is of 3-4 years (96). The development to sexual maturity is also similar in *T trichiura* and *A lumbricoides*, of 50-80 days (95), although egg production capacity appears to be pronouncedly higher in *A lumbricoides* than in *T trichiura* (10,000-200,000 and 2,000-20,000 eggs/female worm/day, respectively) (97-99).

Environmental conditions strongly influence the transmission of both nematodes, so that the free-living egg stages present in the environment develop and die at temperature-dependent rates (97). According to experimental studies, the maximum development rates of free-living infective stages occur between 28 and 32 °C, with the development of both species arresting below 5 and above 35-39 °C (100,101). Eggs of *A lumbricoides* appear to be more resistant to extreme temperatures than those of *T trichiura*, with a life expectancy of the free-living infective egg stage of 28-84 days for *A lumbricoides* and of only 10-30 days for *T trichiura* (97-99). This development in the soil (see figure 1 I) appears to be less rapid than that of hookworm larvae, and consequently they have a lower probability of surviving to infect hosts, according to the observed relationship between prevalence and the number of days in the year below the thermal threshold. The prevalence of *T. trichiura* and *A lumbricoides* is generally low in locations where temperatures fall below the thermal threshold for less than 35-40 days, and increases with increasing number of days (96).

The larval development time inside the egg up to infective stage shows a wide range (*T trichiura*: 20-100 days; *A lumbricoides*: 8-37 days) (100, 101), which is also influenced by soil moisture and relative atmospheric humidity. A higher humidity is associated with a faster egg development, and at a low humidity of less than 50% the eggs of both species do not even embryonate (96).

These different development and survival rates will influence parasite establishment in the human host and consequently the infection levels. A climate-induced increase in the rate of establishment, while holding parasite mortality constant, causes the parasite equilibrium to rise (102). Although transmission may present seasonal dynamics, the fluctuations may be of little significance, because the life span of adult worms is much longer than the year periods during which R_0 is less than 1. In that way, R_0 on average will be greater than 1 and maintain the overall endemicity (97). Thus, spatial variability in long-term synoptic environmental factors will have a greater influence on transmission success and patterns of nematode infection than seasonal variability in a location (96).

The importance of climate on the transmission explains the statistical relationships observed between environmental factors and spatial patterns of infection by these two nematode species. There are many reports on the ecological associations between the distributions of these nematodes and temperature, rainfall and altitude (103).

RS and GIS have been used successfully to describe the environmental factors associated with infection patterns by *T trichiura* and *A lumbricoides* in selected geographical areas, and have helped in identifying the importance of different environmental factors in determining geographical distributions (104-109). A clear relationship exists between infection prevalence and remotely sensed land surface temperature (110): *T trichiura* and *A lumbricoides* prevalences are generally less than 5% in areas where land surface temperature exceeds 38-40° C. This is opposite to what happens with hookworms, despite all these nematodes presenting a similar thermal thresholds. The eggs of *T trichiura* and *A lumbricoides* are non-motile and cannot consequently escape from high surface temperatures resulting in egg dying from desiccation (96).

Models applied for *T trichiura* and *A lumbricoides* including independent variables as satellite-derived mean land surface temperature, Normalized Difference Vegetation Index (NDVI) and altitude (96,111), have provided impressive descriptive accuracies both of low and high transmission situations. Satellite data can therefore help define their large-scale distributions, which are demonstrated to be influenced by heterogeneities in climate. Unfortunately, other factors as human behaviour, personal hygiene, differences in sanitation and socio-economic status, have to be considered when analysing smaller scale levels.

Other zoonotic ascarid species are also of great public health importance, affect predominantly children and might be affected by climate change by influencing on the egg development in the external environment, although no concrete studies on that subject seem to have been performed up to the present.

Toxocariasis is a zoonotic infection caused by the larval stages of two cosmopolitan species of the ascarid genus *Toxocara*, *T canis* and *T cati*. Their one-host life cycle is similar to that of *A lumbricoides* (112,113), with the exception of the possibility of neonatal and transmammary infection in *T canis* (114, 115) and the participation of rodents as paratenic hosts (116,117). Hosts are infected either with infective eggs developing and surviving in the environment or with larvae from paratenic hosts. *Toxocara canis* is fairly age-specific and therefore hosts of nematode adults are usually puppies, which contaminate the environment with large number of eggs (118). Puppies are infected by the intrauterine or the lactogenic way with larvae activated in the organism of pregnant bitches since the 6th week of pregnancy. Rodents, as paratenic hosts, often significantly contribute to the circulation and maintenance of toxocariasis, as *Toxocara* larvae survive in their organism and are also transmitted to their progeny. *Toxocara cati* parasitizes in all categories of feline carnivores, and unlike puppies, kittens may contract infection only after their birth by lactogenic way.

Transmission of these two animal ascarids to humans primarily results from the ingestion of food or soil contaminated with embryonated eggs. Non-embryonated eggs are shed in the faeces by dogs harbouring the adult worm, mainly massively-infected puppies (119). Although human infection by *T cati* might be underestimated considering the high *T cati* infection rate in cats (120), *T canis* is generally considered the main agent of human toxocariasis (121). In many parts of the USA the prevalence of toxocariasis is almost 100% in puppies less than 6 months of age (122). In developed countries, children, typically 1-4 year old, often come in contact with *T canis* eggs while playing in sandboxes and on playgrounds that were contaminated by a family pet. In developing countries, infection in children, in rural areas where dogs and cats are present, may be higher due to mainly the lack of veterinary control of these domestic animals. In humans, *Toxocara* worms never reach the adult stage, their larval stage causing both visceral and ocular larva migrans (123). Visceral larva migrans is mostly a disease of toddlers and young children, whereas ocular larva migrans is more common in 5-10-year older children. Both the habitat of geophagia and having a litter of puppies in the home have been identified as significant relative risk factors for the development of toxocariasis (124, 125).

ANCYLOSTOMIASIS, NECATORIASIS AND CUTANEOUS LARVA MIGRANS

Among soil-transmitted nematodes, the two ancylostomid geohelminth species *Ancylostoma duodenale* and *Necator americanus* (hookworms) are transmitted by free-living larvae. Hookworms are present in tropical and subtropical regions of the developing world lacking appropriate hygienic conditions (see figure 1 I). Recent estimates indicate that hookworms infect 740 million people, the majority in areas of sub-Saharan Africa, East Asia, China, India and South America (94). Hookworm infection occurs in almost half of the poorest people in sub-Saharan Africa, including 40–50 million school-aged children and 7 million pregnant women, in whom it is a leading cause of anemia (71).

For hookworms, the estimated values of the basic reproductive number R_0 are between 2 and 3, and consequently lower than for the pseudogeohelminths *T trichiura* and *A lumbricoides* (95). Compared to the two pseudogeohelminths, hookworm adult life span is longer (3-4 years), adult development to sexual maturity is shorter (28-50 days) (95), and egg production is lower (3,000-20,000 eggs/female worm/day) (97). Their long adult survival is a crucial factor, as life within the host represents a parasite life period not influenced by environmental conditions. This characteristic pronouncedly increases the chances of hookworm transmission stages to be deposited and develop in appropriate temperature conditions.

Hookworm free-living larval stage development and survival pronouncedly depend on environmental conditions (97). The time needed for larvae to develop up to infective stage is of 2-14 days (126) and the life expectancy of the free-living infective larval stages is of 3-10 days (97), both markedly shorter than in *Trichuris* and *Ascaris*. Thus, the probability of hookworm larvae surviving to infect hosts is enhanced by their more rapid development in the soil. This is related to the observed relationship between prevalence and the number of days in the year below the thermal threshold. When compared to *Trichuris* and *Ascaris*, hookworms require a much smaller (8 day) window of thermal suitability for transmission and consequently they are able to persist even when the period available for development is of only 10 days (96). The abundance of hookworm larvae is also related to soil moisture and relative atmospheric humidity, maximum survival rates of hookworm larvae, that is proportion of surviving larvae, being within the 20-30 °C range, their development ceasing at

40 °C (126). These development and survival rates will influence parasite establishment in the human host and consequently infection levels (97).

Hookworm infection appears to be highly prevalent throughout the upper end of the thermal range, which is opposite to *Trichuris* and *Ascaris* in spite of having similar thermal thresholds. The hookworm capacity to survive under hotter conditions may be related to the ability of their mobile larvae to migrate to more suitable thermal and moisture conditions. The motility of hookworm larval stages, although limited, enables them to avoid desiccation by moving downward into the soil (127).

Ancylostomids are peculiar because of their capacity to enter in hypobiosis, which enables them to survive periods that are not suitable for transmission (128). However, in human ancylostomids hypobiosis only occurs for *A duodenale* (129) and not for the sub-Saharan Africa predominant hookworm species *N americanus* (130). Therefore, hypobiosis has been excluded as a possible explanation for hookworm's apparent wider thermal tolerance (96).

The relationship between climatic factors and hookworm development is the base to understand the associations detected between hookworm geographical distributions and environmental characteristics (103). This baseline has been applied for RS analyses and GIS development for identifying the importance of the climatic and other environmental factors in the hookworm distributions in concrete geographical areas (104-109,131). These studies may be useful in analyzing the future effects of climate change on hookworm prevalences, intensities and geographical dispersal. However, models including independent variables as satellite-derived mean land surface temperature, NDVI and altitude (96,111), have provided only moderate accuracy when applied for hookworms, a probable reflection of the apparent wider distribution of hookworms than *Trichuris* and *Ascaris* for which those models appeared to be very accurate. Unfortunately, the application of such models at smaller scale levels becomes more complicated, as factors not easily quantifiable as those related to behavioural characteristics of human communities shall be taken into account (96).

Hookworm infections would typically not be considered new or re-emerging as they are highly prevalent throughout the developing world. Infection levels tend to be stable because of the lack of sanitary waste disposal and proper hygiene practices. However, under appropriate conditions, geohelminth infections can re-emerge in areas of low prevalence. A rapid increase in hookworm prevalence that coincided with environmental change including flooding, altered water drainage patterns and saturation of soil near homes, was reported in Haiti (132). The prevalence of hookworm infection increased markedly from 0% to 12-15% over a 6-year period, most of this increase taking place in 3 years. Analyses lead to conclude that the temporally-coincident local environmental change including moister soil conditions because of the flooding favoured hookworm transmission allowing a rapid increase. This case, although not of climate origin, clearly suggests that climate change may have important consequences on hookworm infection at least at local level.

Climate change may be of higher impact on other ancylostomid species of animals which, besides tropical and subtropical regions, also inhabit temperate and colder regions where climate change is expected to be more marked. The species specific and common of cats, dogs and other canids *Ancylostoma braziliense*, *A. caninum*, *A. ceylanicum* and more sporadically *Uncinaria stenocephala* are the main causal agents of cutaneous larva migrans or creeping eruption (133,134). *Ancylostoma braziliense* appears to be the most widely distributed species and the human syndrome it causes is called "larbish" in Africa. The life cycle pattern and dependence from environmental factors of these ancylostomid species is similar to that of *A duodenale*, excepting the participation of paratenic rodent hosts in *A braziliense* (135,136) and the possibility of neonatal and transmammary transmission in *A caninum* (114,115,137). Developmental arrest or hypobiosis allows nematode larvae to persist within the somatic tissues of the host and to reactivate at opportune periods. Reactivation results in resumption of development and self-reinfection or dissemination of the parasite to the environment or to newborn offspring (128,138). The ubiquity of *A caninum* in the domestic dog populations, related to its neonatal transmission, is of concern because of its ability to cause not only cutaneous larva migrans but also gastroenteritis in humans (139).

An emergence of human cutaneous larva migrans was detected in Berlin, Germany, in summer 1994 when extraordinary climatic conditions were observed, leading to the extremely high number of 378 sun-hours in July. During this period, the mean surface air temperature in the area of Berlin was 6 °C higher than the average values of this century and the absolute air humidity was up to 19 g water/m3 air (average value 10 g/m3). The study concluded that increasing local temperatures resulting from climate changes and the threat of global warming may give rise to an emergence of the cutaneous larva migrans syndrome due to the ubiquitous presence of these zoonotic hookworms (140).

FILARIASES AND ONCHOCERCIASIS

Lymphatic filariases by *Wuchereria bancrofti* (Bancroftian filariasis or wuchereriasis) and *Brugia malayi* (brugiasis) and onchocerciasis or river blindness by *Onchocerca volvulus* are highly pathogenic vector-borne nematode diseases transmitted by biting insects belonging to different dipteran families (culicid mosquitoes and *Simulium* blackflies, respectively) and distributed in tropical and subtropical regions of the developing world excepting eastern Asia where they expand northward into template areas. Lymphatic filariasis (46–51 million cases) and onchocerciasis (37 million cases) are also widespread in sub-Saharan Africa, each disease representing a significant cause of disability and reduction in the region's agricultural productivity (71). Loasis by *Loa loa* is another filariasis in Africa, but of low pathogenicity and transmitted by tabanid dipterans.

The most obvious clinical impact of these disease is during adulthood. Therefore, they significantly decrease the socioeconomic status of the affected communities, as expressed in their disease burden estimate in disability-adjusted life years (DALYs) (141). Consequently, children living in these communities are indirectly affected by the disease impact. Additionally, although human prevalences increase with age and are therefore usually not considered problematic diseases in children, infection by *W bancrofti* in children appears associated with the infection status of both parents, implying differences in exposure at the household level and not in utero exposure per se as the major determinant of infection in children. A similar familial clustering has also been observed in *B malayi* infection (142). Moreover, prevalence differences with regard to age are known to be related with transmission intensity in the endemic area in question. Thus, in high wuchereriasis transmission foci adult subjects are those more affected, whilst in low transmission foci prevalences grow in young children to become stable around 15 years age and more (143).

In humans, adult worms follow a long development, with beginning of offspring microfilariae production after a year or longer, and have a very long life span of several years. On the contrary, the development within the vector is short, of only a few weeks. The duration of the parasite development inside the vector may vary according to vector species or strain, but mainly depending on enviromental temperature.

Wuchereriasis appears concentrated in foci. Infection by filarids can only take place when transmission conditions are very adequate, among which temperature and abundance of surface waters for mosquito vector development are the most important factors (143). Infected mosquitoes maintained at 16 °C survive for months but filarid parasites do not develop. The minimum temperature threshold for filarid development inside the vector is 18 °C; at this temperature they take 48 days to complete their larval development until infective stage. At 20 °C the development is completed in 27 days, at 25 °C in 14 days, and at 30 °C in only 10 days. At higher temperatures of 32-33 °C, the parasite does not appear to reach a viable infective stage, which occurs parallely to a high mortality of female mosquitoes. Thus, temperature acts on both parasite development and vector survival, mean temperatures of 23-27 °C appearing to be the most appropriate for the transmission. The influence of temperature on transmission intensity is so high that it is sufficient by itself to clearly design the geographical distribution of the disease by interacting with both latitude and altitude, with only a very few exceptions (143,144).

For the disease to be intensely transmitted, vectors shall also be abundant, which occur when larval development sites are numerous at least during a short period (heavy rainfall on impermeable flat soil) or when several larval development sites are maintained throughout the year (permanent water bodies). Extreme climatic events strongly modifying the stable ecology of the aquatic environment give rise to quick mosquito population decreases. In many areas, it has been observed how wuchereriasis distribution appears linked to the frequency of precipitations and to the abundance and long-term stability of surface waters (143,144). The broad literature dealing with the potential impact of climate change on mosquito vectors can be extrapolated to filariases.

In French Polynesian archipelagos, wuchereriasis transmission potential and resulting disease manifestations in humans proved to be correlated with ambient temperature (145). In East Africa, a marked seasonal variation in vector abundance and transmission potential contributes to a complex transmission pattern, with indices being higher during and shortly after the rainy seasons. Considerable differences in *W bancrofti* transmission were thus observed within a relatively small geographical area, reflecting in the marked differences in infection level in the human populations (146). Differences in infectivity rates of Bancroftian filariasis vectors also appear between the wet and dry seasons in Kenya (147), similarly as in India (148).

RS and GIS have been attempted for filariasis (103,106,107), loasis (149) and onchocerciasis (150-152). These studies have focused on the use of RS data to identify ecological correlates of infection and develop statistical models of disease risk.

A rapid mapping method has been developed for wuchereriasis. A Rapid Geographical Assessment of Bancroftian Filariasis (RAGFIL) has been developed by TDR/WHO. This is based on the use of a spatial sampling grid with either 25 km or 50 km between sampled communities, rapid prevalence assessments, and geostatistical methods for predicting the distribution of filariasis throughout the target area (153). Prevalences in four countries in West Africa have been predicted using this method (154).

Onchocerciasis has also been included within the list of diseases which may increase with global warming (73). Blackflies breed in areas close to fast-flowing and well-oxygenated rivers and seldom travel more than 15 km in search of a bloodmeal. This means that high-prevalence communities are located close to breeding sites. Consequently, not only global warming but also climate change effects linked to water-related variables, such as rainfall or extreme climatic events as well as droughts, able to modify freshwater bodies and their water velocity, may have an impact on onchocerciasis.

In western and southwestern Ethiopia, different models based on altitude, temperature, rainfall, evapotranspiration, NDVI and terrain slope were useful to predict high to severe risk areas, including suitable areas for onchocerciasis transmission even outside known endemic areas (151). In southern Venezuela, GIS tools and a landscape epidemiology approach showed striking differences in the transmission dynamics of onchocerciasis between different river courses. A significant relationship wih temperature and influences by the geologic substrate, kind of landscape and vegetation were observed. Different kinds of landscapes associated with different vector species were linked with different transmission intensities (152).

Rapid Epidemiological Mapping of Onchocerciasis (REMO), developed by TDR (Tropical Disease Research)/WHO, has been a key geographic tool for the control of onchocerciasis (155,156). REMO uses geographical information, particularly the locations of river basins, and makes it possible to assess which communities are at high onchocerciasis risk and where they are located. The robustness of REMO following several rounds of interventions remains, however, to be fully investigated since there has been little validation of the approach since its initial development (96).

CONCLUDING REMARKS AND FUTURE WORK

Helminthiases are nowadays included within the so-called neglected tropical diseases (NTDs), a group of chronic, debilitating, and poverty-promoting parasitic, bacterial, and some viral and fungal infections, which are among the most common causes of illness of the poorest people living in developing countries. Their control and elimination is now recognized as a priority for achieving United Nations Millennium Development Goals and targets for sustainable poverty reduction (157). Helminths together comprise the most common infectious agents of humans in developing countries. The collective burden of the common helminth diseases, including from dramatic sequelae to the more subtle but widespread effects on child development, pregnancy, and productivity, rivals that of the main high-mortality conditions such as HIV/AIDS or malaria (158).

Around 85% of the NTD burden for the poorest 500 million people living in sub-Saharan Africa results from helminth infections. The DALYs for total helminth infections in sub-Saharan Africa is 5.4–18.3 million in comparison to 40.9 million DALYs for malaria and 9.3 million DALYs for tuberculosis (71). In the Latin American and the Caribbean region, approximately 40% of the estimated 556 million people inhabiting that region live below the poverty line. Relative to sub-Saharan Africa and Asia, the character of poverty in the Latin American and the Caribbean region is unique. Of the Latin American and the Caribbean region’s estimated 213 million impoverished people, around one-third live in rural poverty as subsistence farmers, ranchers, and fishermen (159), typically in communities of indigenous and African descent where they face a high level of social exclusion and social inequity, including lack of access to safe water and health care services. Two-thirds of the region's poor live in urban and peri-urban communities where poverty combines with the conditions of unsafe water, poor sanitation, and the proliferation of rodent animal reservoirs and vectors (160). Poverty is not the only major determinant for risk of acquiring NTDs in the Latin American and the Caribbean region. Instead, it combines with other inequities related to ethnicity (e.g., indigenous groups and people of African descent), age and gender (i.e., children and women), and a patchwork of unique ecological niches to establish sometimes highly focal epidemiological NTD ''hot spots.'' This has important implications for the control of NTDs in the Latin American and the Caribbean region, which may differ from the integrated NTD control currently being advocated for and tested in sub-Saharan Africa and elsewhere (157).

Yet, research into helminth infections has not received nearly the same level of support. This is partly because helminthiases are diseases of the poorest people in the poorest regions, but also because these pathogens are difficult to study in the laboratory by comparison to most model eukaryotes and many other pathogens (71).

Climate change has been highlighted as the biggest global health threat of the 21st century (1). As it has been shown above, effects of climate change on trematodiases and nematodiases will unavoidably interact with efforts to be made to achieve the United Nations Millennium Development Goals. A new advocacy and public health movement is needed urgently to bring together governments, international agencies, non-governmental organisations (NGOs), communities, and scientists and academics from many disciplines to face the effects of climate change on health. Management of the climate change effects on helminthiases will require inputs from all sectors of government and civil society, collaboration between many scientific and academic disciplines, and new ways of international cooperation.

Broad integrated and multidisciplinary initiatives are in need to be organized to assess and counteract these effects where they can be more devastating, as in poor rural areas and and remote communities of developing countries. Action should be taken to launch large and long-term multidisciplinary projects including several year studies in both the field and the laboratory to assess how climate change will modify the present scenarios of prevalences, intensities and geographical distribution of diseases of such high impact on rural children as trematodiases and nematodiases. Obtaining such new knowledge becomes crucial for the establishment of forecasting measures, for decission makers to conclude priorities on where and when to intervene, and for gouvernments and health officers to design the appropriate public health systems that should be put into place to deal with the future adverse outcomes.

Fortunately, we already have the sufficient base knowledge as well as the tools for research, assessment and monitoring needed for such an action. However, many aspects do not conform an easy scenario, due to the long duration of the initiatives needed, the high cost of field and laboratory research activities in both remote rural areas and high technologies as parasite life cycle experimental reproduction, molecular characterization of parasites and vectors, and large computer requirements for mathematical modelling, RS and GIS analyses, and the evident difficulties in starting broad international collaboration initiatives between experts of disciplines not used to interact. Among all this scenario, the importance of re-increasing efforts on field work in the rural areas has been recently highlighted (161).

Helminth infection takes long time to react to climatic and environmental changes, even also after extreme catastrophic events. It will not be easy to adapt to long-term efforts, both for funding institutions not to become tired in keeping support and for scientists not to be frustrated due to the slow climate-change modifications in disease characteristics during long periods, in the present society always in hurry and increasingly demanding short-term production and success. But future risks represented by climate change effects on children living in rural areas of developing countries are too important as to ignore them. Our responsibility towards future generations requires immediate action. A hard work is in front of us.

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Chapter 11

IMPACTS OF CLIMATE CHANGE ON AEROALLERGENS AND ALLERGIC RESPIRATORY DISEASES IN CHILDREN IN RURAL AREAS

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Impacts of climate change on aeroallergens and allergic respiratory diseases have been assessed and reviewed previously, but this previous research has not focussed on such impacts in children in rural areas. The aim of this chapter is to provide an up-to-date, international, and holistic review of this topic. The chapter includes, for the first time, an assessment of changes in two extreme events, thunderstorms and tropical cyclones, and the resulting impacts on aeroallergens and allergic respiratory diseases in children in rural areas. The impacts of climate change, and in particular increases in atmospheric carbon dioxide concentration and temperature, may include for some plant species increases in pollen production, atmospheric pollen concentration, and pollen allergenicity, an earlier start to the pollen season, and changes to plant and pollen spatial distribution, such as poleward and upward range shifts. Climate change may also have an impact on allergic respiratory diseases in children in rural areas through impacts of extreme events on aeroallergens, including ‘thunderstorm asthma’ and ‘tropical cyclones, flooding and indoor mould’. Both mitigation and adaptation responses to these impacts are required. Examples of adaptation include enhanced aeroallergen monitoring and forecasting, tighter management of allergenic plant species, and continued research in particular aspects of this topic.

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INTRODUCTION

Climate change has had, and will continue to have, many significant adverse impacts on human health. While the impacts of climate change on aeroallergens and allergic respiratory diseases in children in rural areas have not been the focus of published reviews to date, various aspect of this topic have been. The impacts of climate change on aeroallergens were reviewed by Beggs (1) and the resulting impacts on allergic respiratory diseases have been explored recently by Beggs and Bambrick (2) and Shea et al (3). Schmier and Ebi (4) recently examined the impacts of climate change and aeroallergens on children's health (specifically asthma), but only for the United States (US) and without a focus on rural health.

The aim of this chapter is to provide an up-to-date, international, and holistic review of this topic. Examination of the impacts of climate change on aeroallergens and allergic respiratory diseases, with a focus on children in rural areas, is important for several reasons. Rural areas present a somewhat different set of public health issues compared to urban areas (5). These include, but are not limited to, generally greater distances to access health and medical services, a different set of environmental contaminants, and so on. Similarly, children present a somewhat different set of public health issues compared to adults (6). For example, the prevalence of some diseases is different, and for some diseases much greater, in children. This is the case for asthma, with epidemiological studies around the world finding a higher prevalence in children than in adults. Indeed, asthma is the most common chronic disease among children, with recent International Study of Asthma and Allergies in Childhood results showing the global prevalence of asthma symptoms (current wheeze) in 13-14 year olds in the past 12 months at 14.1% (7).

The following discussion first reviews the impacts of climate change on rural aeroallergens, and in particular pollen, including impacts on pollen production and atmospheric pollen concentration, pollen allergenicity, pollen season, plant and pollen spatial distribution, and fungal spores. Impacts of extreme events on aeroallergens and allergic respiratory diseases are then discussed, using two case studies, ‘thunderstorm asthma’ and ‘tropical cyclones, flooding and indoor mould’, of particular relevance to rural environments. The final section of the discussion considers responses to the impacts outlined above. Both mitigation and adaptation are considered.

DISCUSSION

Many aspects of the observed past, and projected future, changes in climate have the potential to impact on aeroallergens and allergic respiratory diseases in children in rural areas. These include increases in atmospheric carbon dioxide concentration and temperature, changes in precipitation and the circulation of the atmosphere, and increases in the frequency and/or intensity of thunderstorms and tropical cyclones.

Impacts of climate change on rural aeroallergens

Pollen production and atmospheric pollen concentration

There are two lines of evidence that suggest that increases in atmospheric carbon dioxide concentration ([CO_2]) and temperature can result in increases in pollen production and atmospheric pollen concentrations. Experimental research where ragweed (*Ambrosia artemisiifolia*) has been grown at pre-industrial, current, and potential future [CO_2]s has found that pollen production in this species is significantly increased at current compared to pre-industrial [CO_2] and also at potential future compared to current [CO_2] (8). Similar research, comparing pollen production in ragweed grown in the higher temperature and [CO_2] of an urban environment to that grown in the adjacent rural environment, also found increased production in this species in the conditions of the urban environment: analogous to a future global atmosphere (9). Common ragweed is the principal source of pollen associated with seasonal allergenic rhinitis in the US, and is spreading in other parts of the world such as Europe (10). The results of these experimental studies therefore have important public health implications, including for vulnerable children in rural areas.

Atmospheric pollen concentrations have been monitored at many locations around the world, and records extending over one or more decades during the last half century or so exist for locations in Europe, Japan, and North America. Many of these records show an increasing trend in pollen concentration for important allergenic species such as birch (*Betula*) (e.g., Yli-Panula et al (11)), alder (*Alnus*) (e.g., Bortenschlager and Bortenschlager (12)), and Japanese cedar (*Cryptomeria japonica*) (13). In some cases the increasing trend has been associated with increasing regional temperatures (11). These records therefore suggest that climate change may already be having an impact on atmospheric pollen concentrations.

Pollen allergenicity

Very little is known about the impacts of climate change on pollen allergenicity (here defined as the allergen content or concentration of the pollen grain). Research by Singer et al (14) found that ragweed grown at a potential future [CO_2] produced pollen that was significantly more allergenic that pollen produced by plants grown at both current and pre-industrial [CO_2]. There is also some evidence to suggest that higher air temperature can lead to more-allergenic pollen in birch (15-16). This is supported by more-recent research by Tashpulatov et al (17).

Pollen season

The extended monitoring of atmospheric pollen concentrations referred to above has also enabled changes in the timing and length of the pollen season to be examined. Such studies have generally found that the start of the pollen season is getting earlier (11). For example, Van Vliet et al (18) analysed daily pollen counts for 14 plant species or families from 1969 to 2000 in the western part of the Netherlands, and found an advance of the mean start of the pollen season of 3 to 22 days for the decade of the 1990s compared to the decade of the 1970s. The results also indicated that there was a strong correlation between temperature and the start of the pollen season. This finding of a trend to earlier pollen season starts is consistent with phenological research showing that timing of many other plant and animal phenomena, such as flowering, is also getting earlier in response to increasing atmospheric temperatures (19).

A clear trend in the timing of the end of the pollen season, and therefore the overall length of the pollen season, has not been found. Some studies have found that the end of the pollen season has either remained constant or got later, so when combined with an earlier start resulting in a longer overall pollen season (10), while other studies have found that just like the start of the pollen season, the end of the pollen season is occurring earlier, resulting in little or no overall change in the length of the pollen season (10). In terms of projected future changes in the timing of the pollen season, several modelling studies indicate a continuation of the trend to an earlier pollen season (20). Unless the trend to earlier pollen season starts is clearly communicated to those with allergic respiratory disease and their carers and related health care professionals, and local aeroallergen monitoring and forecasting continue so that management and prevention of symptoms can occur, there exists the danger that adverse health impacts will result into the future.

Plant and pollen spatial distribution

Very few studies have directly examined the impacts of climate change on the spatial distribution of allergenic plants or the dispersion of their pollen. However, based on the most recent assessment of the Intergovernmental Panel on Climate Change (IPCC) (21), that there is very high confidence that recent warming is resulting in poleward and upward shifts in ranges in plant species, such shifts are likely to be occurring in plant species that produce clinically important pollen. Emberlin (22) has suggested such shifts in the range of *Betula* in the Northern Hemisphere are likely with future climate change. For future increases in global average temperature exceeding 1.5-2.5°C, there are projected to be major changes in species' geographical ranges (21). The implications of these changes for children in rural areas are that their pollen exposure may change over time, with the potential for a decrease or disappearance of some pollen types, and an increase or appearance of other pollen types.

In addition to these changes in plant ranges, changes in atmospheric circulation patterns may have an impact on the dispersion of pollen (22). It has also been suggested that increasing air temperature may enhance atmospheric instability, thereby altering the turbulent airflow that transports pollen (23).

Fungal spores

Although the subject of much less climate change research than plants and pollen, there is evidence to suggest that climate change impacts on fungal spore concentrations, allergenicity and seasonality. The most notable observational study to date is perhaps that by Corden and Millington (24), of *Alternaria* spores in the atmosphere of Derby, UK, from 1970–1998. *Alternaria* spore concentrations showed a distinct upward trend over this period, and there was evidence of an earlier *Alternaria* spore season start and an increase in the season duration (24). These changes were associated with an increase in cumulative winter and early spring temperatures in Derby over the same period. The increasing *Alternaria* spore concentrations were also associated with increases in asthma and rhinitis symptoms. The clinical importance of *Alternaria* exposure in children in rural areas has been demonstrated by Downs et al (25), who concluded that *Alternaria* allergens contribute to severe asthma in regions where exposure to the fungus is high. Therefore, if these trends in *Alternaria* concentrations and seasonality were to continue in the future for this and other fungal species and in other locations, then the adverse impacts on children in rural areas could be considerable.

Impacts of extreme events on aeroallergens and allergic respiratory diseases

Thunderstorm asthma

Epidemics of asthma associated with thunderstorms have been reported in the literature since at least the mid 1980s, in Australia, Canada, and the United Kingdom, including rural locations such as Wagga Wagga in inland New South Wales. The phenomenon has been observed in both adult and child populations, with, for example, the study by Dales et al (26) examining records of asthma emergency department visits from a children's hospital. A number of environmental conditions and mechanisms now appear to be involved in such epidemics (27). The first is that there must be an abundance of potentially allergenic biologic material, specifically grass pollen and fungi (27), which explains why most of the reported epidemics occurred in the grass pollen season. Second, as was first described by Marks et al (28), an outflow of colder air associated with the downdraught from a thunderstorm, sweeps up pollen grains and/or fungi and concentrates them at ground level. A third environmental factor is the formation and presence of respirable allergenic particles. Suphioglu et al (29) demonstrated that rye-grass pollen grains are ruptured in rainwater by osmotic shock, with each grain releasing about 700 allergenic starch granules into the environment. Unlike the relatively large intact grass pollen grains which are too large (>35 μm) to enter the airways, these starch granules are very small (<3 μm) and respirable. Similarly, the involvement of damaged or broken *Alternaria* species spores, that more easily access the lower respiratory tract, in thunderstorm asthma has been described by Pulimood et al (30) and Corden and Millington (24). Farming practices in rural areas contribute to the abundance of whole and fragmented fungal spores, with *Alternaria* and other fungal species growing on cereals, and suggestions that mechanised harvesting is a cause of spore fragmentation (24,30).

Evidence is now starting to emerge that climate change will include important changes to thunderstorms. In a climate model study of severe thunderstorm frequency in the United States by Trapp et al (31), a net increase in the number of days with large-scale (or environmental) meteorological conditions that foster such thunderstorms during the late 21st century was found. In another recent climate model study, this time of the European region, Marsh et al (32) found seasonal variability in changes to some conditions favourable for severe thunderstorms, but for most locations there was an overall small increase in favourable severe thunderstorm environments. These projected future changes to thunderstorms, combined with increases in atmospheric pollen and mould spore concentrations and pollen and mould spore allergenicity described in previous sections, imply considerable adverse future impacts on children in rural areas with allergic respiratory diseases.

Tropical cyclones, flooding and indoor mould

Tropical cyclones (also known as typhoons and hurricanes) and flooding have been the cause of dramatic increases in atmospheric mould spore concentrations and increases in asthma. Several factors, including heavy precipitation, storm surge, and flooding, typically result in extensive water-damage to homes and other buildings in tropical cyclone affected areas. It is this water damage that can result in the rapid and prolific growth of mould and then the release of mould spores into the atmosphere. Hendrickson et al (33) found a significant increase in physician visits for asthma for the rural community on the Hawaiian Island of Kauai in the two weeks after it was struck by Hurricane Iniki, although increases in aeroallergen exposure as a cause of this increase was neither examined nor discussed in this study. Studies of the environmental and public health impacts of Hurricane Katrina provide perhaps the most comprehensive picture of potential hurricane impacts on aeroallergens and allergic respiratory diseases. Solomon et al (34) performed airborne sampling for mould spores in flooded and nonflooded areas of New Orleans during the 2 months after the flooding caused by Hurricane Katrina (29 August 2005) and Hurricane Rita (22 September 2005). They found that the mean outdoor spore concentration in flooded areas was high and roughly double that in nonflooded areas, and that the highest concentrations were found inside homes (34). A study by Rabito et al (35) of mould levels and children's respiratory health in New Orleans at two time points after Hurricane Katrina, suggested that mould levels decreased over the period 6 to 9 months after the hurricane, particularly outdoors, and that the proportion of children with respiratory symptoms was higher 6-7 months after the hurricane compared to both the latter period of 8-9 months after the hurricane and the period before the hurricane (35).

Tropical cyclones are projected to become more intense, with larger peak wind speeds and more heavy precipitation, as climate changes into the future (36). Because tropical cyclones are generated over warm tropical oceans between about 5° and 20° latitude, these projected changes in tropical cyclones would primarily affect coastal communities in this region of the world, including children in rural and remote coastal communities.

Responses

From a climate change perspective, two basic response strategies to the potential impacts on aeroallergens and allergic respiratory diseases in children in rural areas exist: mitigation and adaptation. Mitigation, as defined by the IPCC, is technological change and substitution that reduce resource inputs and greenhouse gas emissions per unit of output. Although several social, economic and technological policies would produce a greenhouse gas emission reduction, with respect to climate change, mitigation means implementing policies to reduce greenhouse gas emissions and enhance sinks (37). While mitigation efforts must continue, adaptation is also required as a result of inevitable climate change. Whereas mitigation focuses on greenhouse gas concentration reductions, adaptation in the context of climate change is simply defined as initiatives, measures and adjustment in natural or human systems in response to actual or projected climate change or its effects, which moderates harm or exploits beneficial opportunities (21).

Adaptation

Knowledge of adaptation strategies in many systems and sectors, including human health, and regions, is relatively limited, and this is particularly the case for adaptation strategies specific to the potential adverse impacts of climate change on aeroallergens and allergic respiratory diseases in children in rural areas. As such, adaptation is a particularly active area of climate change research at present, and this is likely to continue into the future. Although a comprehensive assessment of adaptation is not the focus of this chapter, the following provides a summary of what is known about adaptation in this area.

Although there is good aeroallergen monitoring in some parts of the world, in others such monitoring is sparse or absent (38). Enhanced aeroallergen monitoring is required in such areas, including in many rural locations. Similarly, aeroallergen forecasting currently occurs in some locations, but is limited or absent in many other locations around the world. Enhancement of such forecasting will enable both children with allergic respiratory diseases and their carers (parents, teachers, and health professionals) in more locations to better manage within-season variability of aeroallergen levels.

Another adaptive measure would be tighter management of allergenic plant species. For example, government authorities could consider more carefully which plant species are used in populated areas (1). The use of such measures to fight ragweed expansion in Europe has been discussed by Rybníček and Jäger (39). Similarly, private individuals could transform their gardens into low allergen gardens by planting low or non allergenic species.

Continued research is required. This includes: further climate model studies of future changes in thunderstorms; continuation of long-term aeroallergen monitoring so that future trends in aeroallergen concentrations and seasonality are monitored; much more experimental research on impacts of elevated [CO_2] and temperature on pollen and allergen production of more plant species; modelling and surveillance of future changes in allergenic plant ranges; and research into adaptation in this area.

Public health professionals, like others in the health and medical system, have an advocacy role in persuading governments at all levels around the world to maintain awareness and appropriate actions with respect to climate change (40). This, the other adaptation measures briefly described above, and other adaptation measures for impacts of climate change on aeroallergens and allergic respiratory diseases have been overviewed and critically reviewed recently by Beggs (41).

CONCLUSIONS

Climate change will have impacts on aeroallergens and allergic respiratory diseases in children in rural areas, and these will mostly be adverse. Increases in atmospheric carbon dioxide concentration and temperature will be particularly important. For at least some plant species in some locations, climate change is likely to result in increased pollen production and atmospheric pollen concentrations, and increased pollen allergenicity. It seems likely that the start of the pollen season will continue to get earlier, and there will be poleward and upward shifts in ranges, for many plant species. Changes in extreme weather events such as thunderstorms and tropical cyclones, will also be important, with both of these associated with dramatic increases in aeroallergen concentrations and outbreaks of allergic respiratory diseases. Children in rural areas are particularly vulnerable to these environmental changes, with, for example, particular aeroallergens such as *Alternaria*, being particularly common in rural areas, and children having a greater prevalence of asthma. Mitigation and adaptation responses are required now and into the future. All those with an interest in public health have an important role to play in the response to this important issue.

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Chapter 12

CHALLENGES AND SOLUTIONS IN THE PROVISION OF HEALTH TO THE RURAL BEDOUIN POPULATION IN SOUTHERN ISRAEL

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The Bedouins in the south of Israel are in a state of transition and adaptation to non-traditional lifestyle and abandonment of the nomadic way of life into a change to permanent housing in small towns and authorized villages. This development has been encouraged by the government that provides infrastructure and incentives. However, about eighty thousand Bedouins do not reside in those settlements. Most of them are scattered in permanent houses, huts or tents in remote rural places. Living outside of town means no electricity, no running water, no sewage system, no paved roads, no mail address and no phone lines. Climate changes impose additional burden on this population. The purpose of this chapter is to describe the challenges and some of the solutions in providing health care to this population.

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INTRODUCTION

The Bedouins who reside in the Negev, southern Israel, are in a state of adaptation to non-traditional lifestyle. Restrictions in crossing the borders to neighboring countries, a small country and the rapid increase in the density of the Bedouin population forced them to abandon the nomadic way of life into permanent housing in small towns and authorized villages. This was encouraged by the government that provides infrastructure and incentives. However, about eighty thousand Bedouins do not reside in those settlements. Most of them are scattered in permanent houses, huts or tents in remote rural places. Living outside of town means no electricity, no running water, no sewage system, no paved roads, no mail address and no phone lines. Climate changes impose additional burden on this population. The purpose of this chapter is to describe the challenges and some of the solutions in providing health care to this population.

THE POPULATION

The crude birth rate of the Bedouin population in southern Israel is record high (1) at 44 per 1,000 meaning that the population doubles every 25 years. The complete fertility rate is 7.3. Sixty one percent of the population is below the age of 17 years with the median age of the Bedouins in the Negev at 12.7 years compared with 18.7 and 28.6 to the general Muslim population and the Jewish population, respectively In Israel (2).

In the year 2007 infant mortality rate was 11.5, mostly attributed to problems related to consanguinity marriages (3). Immunization coverage in babies and toddlers was about 80% in the rural areas compared with 90% in the permanent settlements. A dramatic decline in vaccine-preventable communicable disease was recorded in this population (4). Polygamy, although outlawed, is not uncommon and tolerated by the authorities as a matter of respects for the Bedouin Muslim faith (5).

Traditionally, women are in charge of the care for their large families and do not generate income by out-of-home employment. As herding is limited and highly skilled professionals are the exception, the socioeconomic level of the population is low.

CLIMATE AND TERRAIN

The Negev, in the southern part of the state of Israel, is a desert. The average yearly precipitation is below 150 millimeters. Draught is common and this year is the fifth in a row. Temperatures are over 30 degree Celcius during day time in the summer, while nights are chilly and the temperature may drop to zero in winter with the risk of hypothermia in babies.

Most of the Negev terrain is made of limestone. Altitude is between 150 and 1,000 meters above the sea level. Trees are scarce except in the dry riverbeds. There are no freshwater streams or lakes. Waterholes are few and many of them are not properly maintained.

MEDICAL SERVICES

Curative care is provided by Health Maintenance Organizations (HMO), while well baby care is provided by the Ministry of Health. Ninety per cent of the children are enrolled in these services (6). The two systems are loosely coordinated and for inpatient services there is a tertiary hospital in the city of Beer-Sheva (Soroka University Medical Center), which is reachable by car for most of the Bedouins who reside in rural areas within an hour. Traditional and complementary medicine prevails significantly in Bedouin communities (7). Unfortunately, development, modernization and changes in lifestyle impose their toll on Bedouin health. The prevalence of obesity, cardiovascular disorders and diabetes mellitus is increasing (8,9).

POLICY ISSUES

The year of 1995 marked the most significant change in the health care to the Israeli population, when a national health insurance bill was passed. Many Bedouins who could not afford health insurance became eligible to receive free care by the state, which included free visits to a doctor, subsidized medications and free of charge hospitalization. HMOs who, before the bill, were reluctant to provide serviced in rural areas, started to compete, because of the attractive reimbursement by the government. This has resulted in a new trend of increased clinic visits by the Bedouins and more frequent attendance of medical staff in Bedouin communities (10,11).

Mandatory schooling and public awareness have encouraged young Bedouins to graduate medical schools in Israel or Europe and the lack of physicians is today less of problem compared to decades ago. A national general insurance plan is providing families with children a monthly income based on the number of children at home. This policy is aimed to enable even the poorest families to buy food, medications and basic necessities.

In order to decrease maternal mortality rate and immediate medical care to newborns, the state is paying "delivery- in- hospital" bonus to women, who give birth in a hospital. This policy is probably the most influential factor in the disappearance of home deliveries in the Bedouin population and in the dramatic drop in neonatal tetanus and other causes of neonatal death (6). Mandatory schooling for all children contributes to the drop of illiteracy in the Bedouin population and children even in the most remote areas are able to reach school. Schools are used to help in the general effort to affect the health of the population. Beyond immunizations in schools, schools are the place where children are getting health education and they are encouraged to become the vehicle that pass the message to the families.

REACH-OUT MOBILE MEDICAL UNITS

The HMO-" Clalit Health Services" and the Ministry of Health are running mobile units, where medical teams are reaching the population at their residencies (12). . One of the units is a co-venture of Clalit and the Division of Health in theCommunity at the Faculty of Medical Sciences, Ben-Gurion University of the Negev. It is staffed by a physician, a nurse and a social worker. Its services include palliative care at patients homes (13)One of the staff members in the unit is a Bedouin, who facilitates communication with patients and families and is familiar with the area and the rural roads.

The mobile units of the Ministry of Health provide Well-baby-child-care services, which include immunizations, care of pregnant women, health education, surveillance and screenings (14).

WATER

The population of the Negev depend on a water supply by the authorities. Water for agriculture, homes and livestock is reaching the Negev by water pipes from central Israel. The Bedouins in the rural areas do not have water pipelines that reach homes. One of the most popular solutions to the problem is by using a "mobile well". Many families have succeeded to get a mobile water tank and a tractor. Water is supplied in stations along the water pipeline ant the tractor brings water to the dwelling. Compared to the low quality of water from waterholes, this water is checked regularly by the Ministry of Health and from a public health perspective, this water supply helps to eliminate and prevent water-born disease.

POLLUTION

The rural areas in the Negev are the least populated areas in the country. However, some of the chemical and mining industries have used this area as the dumping place for toxic chemicals. These industries are a source to air, water and soil pollution while the population who reside in these area is at increased medical risks. Monitoring of pollutants from the industry and of the health of the population is mandated by the law. It is under control of the Ministry of Health, which is authorized to penal or close plants that cross the limits of pollutants (15,16).

ENERGY, TRANSPORTATION AND COMMUNICATION

The rural Bedouins who do not reside in authorized settlements or towns are not entitled to receive electricity lines to their homes as well as telephone lines. Governmental money to build paved roads is not diverted to these communities. Technical innovations and the rise in the economic abilities of families have coupled to solve these problems. A family-owned mini-generator has become a common commodity and recently, families have started to get sun-collectors to generate electricity. These innovations have enabled families to have a safer source of light (compared with open fire), a way to keep food refrigerated and to operate a television set. However, many are still depended on open fire as the major source of energy. Burn accidents, pollution by smoke and hydrocarbon poisoning in children are still an issue (17).

The camel that was a major help in transportation in the desert lost its glory even in the rural Bedouin communities. Today 4 on 4 transporters and all-terrain-vehicles became popular. They practically eliminated the morbidity and mortality that was related to the inability of the severely sick to get expedited medical help. The cell-phone revolutionized the communication with the people in the rural communities. Practically, it is in every household. Medical services are exploiting the opportunity. Scheduling, arrangements of home visits, emergency calls and communicating with the medical team – all are facilitated by the use of a cell-phone.

Education

Rural Bedouin settlements do not have government-based public buildings. This includes schools, but all the children have to attend schools as schooling is mandatory. Transportation of the children to public schools in Bedouin towns and authorizes villages is organized by the Ministry of Education. School health is provided by the authorities, which include various issues related to healthy life style, nutrition and disease prevention. The idea is that the children will bring the word to their families and start a change based on modern knowledge regarding preventive medicine. For high school children, a special module was developed to convey the medical disadvantaged of consanguinity marriages. It is believed that decreased consanguinity marriages will significantly reduce infant mortality and morbidity in the Bedouin population (18).

The Faculty of Health Sciences at Ben-Gurion University of the Negev is running an extracurricular program for high school students named "Buds of health". Many of the Bedouin children who were enrolled in the program continue their studies in the medical professions and some have graduated medical school.

LOW-TECH SOLUTIONS

Some families, especially those who are the poorest or who live in the most remote places, need innovative solutions for their medical needs. We choose to describe two of them:

- A patient who was released from the hospital with a tracheostomy. For some technical reasons a foot or hand-operated suction device was not an option, but desperately needed. The solution was a suction device that is based on a T-shaped connector to a water pipe. As the water flew throw the pipe, a negative pressure was building-up in the side-tube that was used as a suction tube.
- A patient, with diabetes mellitus, who needed to keep the insulin bottles in a cold place but did not have a refrigeration device in or by home. For that purpose the traditional way of cooling water in unglazed pottery was used. Microscopic pores in the pot enable a slow, but steady evaporation of water. The evaporation kept the temperature of the water low enough to keep the insulin stable in the immersed bottle.

CONCLUSION

Provision of health to the rural Bedouin population is based primarily on the use of old and new technologies coupled with legislations and policies that facilitate care. Improvement in the health of the Bedouins, who reside in rural areas is already well documented. It is hurdled by the imposed constrains of their socioeconomic level. Improvement in the level of education is believed to lead a continuous improvement in the health of this population.

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Chapter 13

MEAT, CLIMATE CHANGE AND GLOBAL CHILD HEALTH

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Animal production is a leading contributor to global greenhouse gas emissions. Different animal products have different associations with disease risks in low and high income countries. Global meat consumption in 2050 should: Optimise direct effects on health in low and high income countries and reduce indirect threats to health from climate change. Target intake patterns need to be behaviourally realistic. Existing patterns of meat intake in British adults were assessed using the National Diet and Nutrition Survey of 2000/1. A meat intake pattern similar to that of the fifth of the British adult population with the lowest current intakes of red and processed meat is a plausible illustrative target for the whole population in 2050: unprocessed red meat 15 g/d, processed meat 5 g/d and white meat 50 g/d. To come within the preferred pattern the other four fifths of the population would need, on average, to make large reductions in their intakes of unprocessed red meat and processed meat. No changes in white meat or fish intakes would be needed. These changes could be expected to materially reduce risks of colorectal cancer, coronary heart disease and diabetes in the UK. If the whole British population were to shift to a pattern of meat intake currently practiced by around one fifth of the population, substantial gains in health and in climate change mitigation could be achieved. More of the sustainable global livestock carrying capacity could then be used to improve child nutrition in low and middle income countries.

INTRODUCTION

The Food and Agriculture Organisation's landmark report on Livestock's Long Shadow, published in 2006, concluded that the livestock sector was 'one of the top two or three most

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significant contributors to the most serious environmental problems'(1) – including climate change. Given that climate change is itself the most important long-term threat to global health (2), it no longer makes sense to base recommendations for animal product consumption on their direct health effects alone. Instead, it is now necessary to consider at the same time both direct health effects and indirect effects via climate change. And because climate change is a global challenge these deliberations need to be framed in their global context. In this brief discussion we wish to:

- Set out, tentatively, some principles relevant to setting targets for animal product consumption;
- Provide an illustrative example of possible targets for meat consumption for mid-century;
- Identify the potential benefits to health – for both high and low income countries – of global convergence towards these target levels.
- Reflect on the main sources of uncertainty and controversy in the issues addressed.

Restraint of animal production for consumers in high income countries can be seen as creating scope for continuing expansion of animal product consumption in low income countries. The most important health benefit of the latter will be the enhanced prospects for child growth and nutrition. This provides the link between this chapter and the main theme of this book.

SOME PRINCIPLES RELEVANT TO TARGETS FOR ANIMAL PRODUCT CONSUMPTION

There is a long history and a large literature on the place of animal products – especially dairy products – in health-favouring diets for children. In general, such foods provide a convenient source of high quality protein and a range of micronutrients. Making 'room' for culturally appropriate increases in animal product consumption in today's low and middle income countries is important, because in populations with marginal or poor nutritional status, increased intake of animal foods has been shown to stimulate weight gain and linear growth in infancy, childhood and adolescence (3). In populations with vegetarian food cultures the relevant animal products will be mainly dairy foods and eggs. Reductions in underweight and increases in linear growth are predictive of better health outcomes in both childhood and adulthood.(4,5)

Optimising health outcomes in today's high income countries

In high income countries, most avoidable health losses occur from chronic diseases incident during adult ages. Intakes of specific types of animal products are implicated in many of these disease risks. Evidence on the association of dairy product and egg consumption with adult disease risks is less consistent than that for meat consumption; this discussion will therefore concentrate on the latter.

Meat and cancer

Recommendation 4 of the World Cancer Research Fund's (WCRF) second report on nutrition and cancer (2007) is to 'eat mostly foods of plant origin' and recommendation 5 is to 'limit intake of red meat and avoid processed meat'. The report recommends that mean consumption of red meat be no more than 43 g/d (ingested, not raw, weight) with 'very little if any to be processed'. The individual-level recommendation for persons who consume red meat is to average less than 71 g/d (6). The report emphasises that it is not recommending diets containing no foods of animal origin.

The evidence that red and processed meat each increased the risk of colorectal cancer was judged, in the WCRF report, to be 'convincing'. For studies that reported risks in relation to exposures measured in g/d, the summary estimate of the relative risk per 100 g of red meat was 1.29 and per 50 g of processed meat it was 1.21 (7).

Meat and vascular and metabolic disorders

A recent systematic review of epidemiological evidence on meat consumption and vascular disease distinguished 'unprocessed red meat' from 'processed meat'. Unprocessed red meat was found to be unrelated to risk of coronary heart disease, whereas processed meat (for which five studies were informative) was found to be associated with a moderate increase in risk. Diabetes risk was also moderately associated with the consumption of processed meat. There were insufficient studies to reach a conclusion on meat consumption and stroke risk (8)

Other evidence from Japan and Honolulu suggests that increases in animal product intake (from historically very low levels) probably contributed to the secular decline in stroke in Japanese populations (9-11). Thus if the optimisation of health outcomes were the only objective, cases could easily be made for a continuing increase (upwards 'convergence') in animal product consumption in low income countries and a downward 'contraction' in red and processed meat consumption in high income countries.

Reducing global greenhouse gas emissions

As already noted, it is now necessary to also consider the potential indirect effects on health from the contribution of animal production to climate change. With each new summary of the scientific evidence on climate change the outlook seems more grim (12). The case for early deep cuts in greenhouse gas (GHG) emissions, especially in high income countries, has become more and more compelling.

The UK has embraced a target or reducing GHG emissions on a per production (territorial) basis by 80% between 1990 and 2050, with virtually all electricity in 2050 planned to come from renewable sources. The UK government – in its 'low carbon transition plan' - foresees '[d]ecarbonising (sic) our whole food chain' and notes that it is 'looking at how emissions throughout the food chain are affected by decisions by business and consumers – including what we buy and eat' (13). But that's really as far as specific as advice to consumers goes. The UK government has so far stopped short of explicitly advocating reduced animal product consumption as a part of its climate policy. A recent Swedish proposal is much more direct: 'To eat less meat and to choose what you eat with care is therefore the most effective environmental choice you can make (14).

The salience of dietary change as a strategy for GHG reduction is much clearer when emissions are counted on a 'per consumption' basis. Over 30 percent of the GHG emissions attributable to the UK population are embedded in (net) imports (15). The food supply accounts for about 20 percent of emissions (on a per consumption basis), without counting second order (land use change) effects. With the latter it is probably around 30 percent (16).

The contribution of meat production to GHG emissions varies markedly by meat type. The estimates are likely to vary between countries with differing production methods. For the UK, estimates based on life cycle analysis (LCA) are that GHG emissions per unit of carcass weight are about 3 times higher for meat from ruminants (beef and sheep) than for meat from monogastric species (poultry and pigs) (17). LCA, however, does not include 'second order' effects – notably land use change to produce more soy and cereals. Land use change contributes substantially to livestock's global warming effects (18) so this could amount to a non-trivial bias in favour of the more soy and cereal intensive monogastric meats (19). Thus some downward ajustment is needed to the 3 fold difference from LCA analysis but it is not currently clear how big this adjustment should be. .

Recommendations for the consumption of different types of meat need to take this – admittedly uncertain - heterogeneity in climate effects into account.

Culturally appropriate, behaviourally realistic and attainable

A fourth principle to be borne in mind when formulating guidance for meat consumption is that the recommended pattern should be realistically attainable.

Consumption objectives are more likely to be attainable where evidence for their feasibility already exists. A pattern of meat consumption that currently exists among substantial fractions of high income populations can be assumed to represent a behaviourally realistic and attainable pattern for whole high income populations in coming decades. Explorations of how intakes of different types of meat tend to co-vary in individuals can help clarify these potentially attainable patterns.

ILLUSTRATIVE TARGETS FOR MEAT INTAKE IN 2050

The economic concept of consumption – which generally refers to the using up of a good such that it is not available for other uses – needs to be distinguished, when discussing food, from what goes in the mouth (which we will refer to as intake). The mean consumption of meat – as estimated by the FAO's Food Balance Sheets, for example – may exceed mean intake by a substantial margin because of wastage, cooking losses etc. This margin tends to be larger in high income countries, as they can afford to waste more (20).

Elsewhere we have suggested 90 g of meat consumed per adult per day as a defensible global target for 2050 – that is, one that low income countries could converge upwards towards and that high income countries could contract downwards towards (21). This might (arbitrarily) be assumed to correspond to a mean intake of around 70 g/d.

In the light of the principles enunciated above, and informed by ongoing work on current intake patterns in Britain (which we will discuss further below), we will propose the following (arbitrary) division of an overall target of 70 g/d (see table 1).

Table 1. Target mean adult meat intakes for a high income country (UK) in 2050, compared to indicative current means for the whole population and indicative current means for the fifth with the lowest intakes of processed meat (average of both sexes, intakes in g/d).

	Current mean intake of whole population*	Target mean intake for 2050	Current mean intake of those in lowest fifth of red and processed meat intakes*	Needed reduction of pop'n mean intake to meet target (%)
Unprocessed red meat	75	15	10	80%
White meat	50	50	55	0%
Processed meat	25	5	5	80%
Total meat	150	70	70	53%

* Indicative intakes based on preliminary analyses of the National Diet and Nutrition Survey, 2000/01. Codes for composite foods containing meat are being disaggregated using estimates of meat content supplied by the Food Standards Agency.

On health grounds alone, the recommendation for processed meat might be zero, but we have compromised a little in the interests of minimising the wastage of cuts that could not otherwise be used.

Table 1 shows that marked reductions will be needed in the overall mean intakes of unprocessed red meat and processed meat in order to reach the intake levels of those who have already adopted a low processed meat dietary pattern. These marked reductions can be expected to yield material gains in health plus substantial mitigation of GHGs. Such a 'double dividend' will in turn strengthen the case to consumers for making the recommended change.

PREDICTED HEALTH BENEFITS

Proper estimates of the effects on aggregated mortality risks of moving from the existing distributions of intakes of different types of meat to our illustrative target pattern require detailed modelling. But some preliminary indication of the magnitude can be gained by estimating the effect on risk of moving from today's mean intakes to the target mean intakes (see table 2).

Table 2. Indicative reductions in risks of colorectal cancer, coronary heart disease and diabetes for individuals with meat intakes at target versus current mean levels.

	Current mean intake (g/d)	Target mean intake (g/d)	Risk reduction per 50/100* g/d	Expected risk reduction (%)
Colorectal cancer – processed and unprocessed red meat				
Processed meat	25	5	17%	7%
Unprocessed red meat	75	15	22%	13%
Joint effect (processed and unprocessed red meat)				19%
Vascular and metabolic diseases – processed meat only				
Ischaemic heart disease	25	5	30%	24%
Diabetes	25	5	16%	13%

* 50 g/d for processed meat and 100 g/d for unprocessed red meat. Risk reduction is 1/RR.

The health gains from shifts to the recommended pattern of meat intake in high income countries such as the UK are thus likely to be worthwhile .

Low income countries – potential benefits from increased intakes of animal products

As already noted, the main health benefits here are expected to come from reductions in undernutrition in childhood – manifest as reductions in underweight and enhanced linear growth. Historically, animal product consumption has risen strongly as incomes have risen and concurrently with this, undernutrition in childhood has decreased, child mortality has declined and adult stature has increased (22).

In the Global Burden of Disease study for 2000, ‘underweight’ (the index used for impaired growth) was the leading cause of lost health in ‘high mortality developing regions’ – and globally (23).

It is important to acknowledge, however, that income effects have not necessarily dominated the decline in child mortality (24). Food intakes are not the only determinant of ‘net nutrition’ in childhood – high burdens of infection also impair growth (25). Reductions in childhood infection have also been sensitive to increases in maternal education and other institutional changes directed towards the control of communicable disease.

There is also at least one important potential benefit to adult health from increases in animal product intakes in populations where such intakes are very low, namely a reduction in stroke risk (as noted above). In many low income countries absolute stroke risks are high and typically dominate vascular risks. The potential health gains from reducing these risks could be substantial.

Although we offer no quantitative estimate of potential health gains from increased animal product consumption in low income countries, they are likely to be substantial. (Note that in populations with vegetarian food cultures the relevant animal products will principally be dairy products and eggs.)

DISCUSSION

Discussion of health and animal product consumption requires recognition of many types of heterogeneity – heterogeneity of health effects by types of meat, heterogeneity in the direction of net effects on health of changes in intake levels in high and low income populations, heterogeneity in contributions to climate change and heterogeneity in consumption patterns in high income countries.

Fortunately, there is the possibility of exploiting these different types of heterogeneity to the benefit of health prospects in both low and high income populations whilst also mitigating climate change. And exploration of the heterogeneity of consumption patterns reveals that patterns of meat intake that are desirable on health and climate change grounds already exist amongst substantial fractions of high income populations. It is a rare good fortune for so much potential synergism to exist on questions of major public health importance. Analyses that fail to work through the implications of this heterogeneity (26) miss important opportunities.

Empirical uncertainties pervade these subjects. Those relating to animal production and climate change include the need to recognise that ruminant production may make use of land unsuitable for other forms of food production and that meat production from monogastric animals (poultry and pork) may place pressures of sources of supply for the needed foodstuffs – including soy – that result in destructive land use change. The risk of vascular diseases in relation to intakes of animal foods has been less investigated than the corresponding risks for cancers. Attempts to infer these risks from hypothesised mechanisms – the effect of saturated fat consumption on cholesterol concentrations (24) – are hazardous when not cross-checked with evidence on direct associations of risks with food intakes. The observed associations between processed meat intakes and risks of coronary heart disease and diabetes lack supporting mechanisms and are based on a small number of informative studies. They should be regarded as provisional until further confirmatory or falsifying analyses are reported.

Notwithstanding these uncertainties, multiple signposts currently point in a similar direction. There is much at stake. To ignore the evidence we already have would be a high stakes gamble.

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Chapter 14

CLIMATE ADVERSITY: YET ANOTHER STRESSOR FOR RURAL ADOLESCENTS

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The idealised rural childhood of freedom, small supportive communities and close connection to the environment does not necessarily serve the psychosocial needs of many adolescents. Factors including locality, social context, infrastructure, service provision and access, labour market, and family and social networks are among determinants of youth mental well being. For rural youth, the problems of isolation and reduced opportunities prompt the most capable to migrate towards larger urban and metropolitan centres for education and employment. There is an adverse impact from the loss of friendships and social support for young people who remain. Coping strategies of rural youth need to be considered in the context of low access to mental health services. Living with drought impacts adversely on family finances, affecting girls and boys differently. Studies in the Australian context demonstrate worsening psychological distress across the community in the face of prolonged drought. Children and adolescents in a drought affected region of New South Wales were participants in two studies, and an increase in psychological distress overtime, and above the general community norms,

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emerged. Concerns about the drought and its impact on self, friends, family and community were also expressed by students who were boarders in rural schools serving drought affected areas. Rural adolescents have higher rates of risk-taking behaviour, with potential adverse effects on health and mental health. The prolonged drought and climate adversity clearly pose a public health problem, and the voice of young people themselves needs to be heard and addressed.

INTRODUCTION

Australian culture has popularised an idealised view of rural lifestyle characterised by perceptions of rural communities as having strong social connectedness and support for residents, contrasting with the longstanding recognition of the environmental hardships and challenges of geographic isolation faced by rural communities (1). This perception is epitomised in the belief that a rural upbringing provides freedom and safety for children to develop and fully enjoy childhood. However there is a growing body of evidence to suggest that the idyllic view of growing up in a rural community may be more valid for childhood rather than adolescence. It is suggested that rural living is viewed as one of safety and freedom in childhood but transforms to one of isolation and limited opportunities in adolescence (2). For example, a 14 year old boy described rural living as “We love the lifestyle – you get lots of experience early like riding motor bikes and shooting” (3). However for older youth rural living can be described as “It’s like living in a gold fish bowl” (2).

Rural youth have reported lacking a voice in their communities (4) and this is mirrored in much of the research on rural youth in that the focus has been on problematic behaviours such as alcohol and drug use, and aggressive behaviour. Australian data highlight important vulnerability of rural youth: lowest rates of educational achievement, higher unemployment, greater social isolation (5). The mental health problems for rural youth cannot be addressed without considering the characteristics of rural communities that are important for youth, namely: locality, social context, infrastructure, service provision and access, labour market, and family and social networks (6,7).

Although farming is only one of the many occupations of rural people, as patterns of agricultural activity and related economies change, farming enterprises in general are reducing in number in Australia, potentially increasing the isolation of farming as an occupation (8). As well as stressors common to urban families such as demands of school, work and conflicting needs of family members, farming families can be subjected to stress as a result of the sharing of responsibilities for farming across family members including children. For example, children in farming families can experience blurred roles as they undertake tasks that directly impact on the economic status of the farm and therefore the family. For both parents and children the lack of a clear distinction between work and home is extremely problematic at times of economic crises as experienced during environmental adversity such as the drought – a common experience in rural Australia.

Given that children and youth perceive financial stress as an uncontrollable event (9) it is not surprising that low family socio-economic status has been associated with increased mental health problems for adolescents (10). There is clear evidence of a gender difference in terms of frequency of worry about financial problems and expression of distress. A Swedish study showed girls worried about family finances twice as often as boys (11), while a study of 15-16 year olds (N=3,809) living in Finnish cities where 18% of families had one or both parents unemployed at some time in the past year showed perceived financial difficulties were associated with depression and harmful drinking for both sexes. For this study, the education level of mothers was associated with harmful drinking in boys and parental unemployment was associated with depression in girls (12).

Studies have shown the risk factors for anxiety in childhood and adolescence that include family factors (parental psychopathology, conflict), community factors (poverty, violence), adverse life events (trauma, abuse) and ongoing stressors (family finance, academic pressure, peer problems) (13,14). A study of 15-19 year old rural adolescents (N=3,553) and their mothers in Mexico found anxiety in adolescents was associated with (i) individual factors such as being female, younger and having lower levels of education; and (ii) family factors, i.e, larger families, and mothers with less education, higher levels of depression and greater perceived stress. The contribution of community factors was not significant and family size explained unique variance in adolescent anxiety even after controlling for maternal mental health (15).

It is important to consider the coping strategies utilised by youth in response to stressors as many rural areas have limited access to specialist services for mental health care (1,16). A study of 12-18 year old youth in a Pennsylvanian farming community found the rural youth had significantly higher rates of avoidance coping than a normative sample. For anger, avoidance coping was used predominantly while for depression and anxiety both avoidance and approach coping was used (17). These findings of the rural boys' limited use of seeking guidance are consistent with low rates of health service use by boys (18). Problematic situations most frequently reported by the rural Pennsylvanian youth concerned family issues (conflicts and financial stress), peer relationships and death of significant others. While relationship issues are of significance in adolescence there is the potential for higher impact of interpersonal conflict for rural youth due to fewer and smaller peer groups (19).

In negotiating the usual developmental demands of adolescence such as separation and individuation from family, development of intimate relationships and attainment of educational and vocational goals, rural youth are confronted with the tension between attachment to place through family networks and the opportunities for education and employment elsewhere (20). Research has shown that it is often the well educated youth with the social capital necessary to move to urban areas for employment or education that leave the rural area (21). This begs the question of how well does the rural community attend to the youth who remain and who are perhaps less able. For some youth leaving the community is a matter of choice or opportunity as being seen as a lack of opportunity for career path locally, a chance to see the world, or to escape the restrictions of the local social environment (22). The out migration of youth from rural communities leads to a loss of friends and therefore social support for rural youth.

LIVING IN DROUGHT AFFECTED COMMUNITIES

The distress associated with drought affects the entire community (23) and rural and remote communities suffer additional disadvantage due to isolation and limited access to health and mental health services (24,25). Loss of the infrastructure and services in rural communities can have an adverse effect of mental health (26). Many important aspects of rural communities are adversely affected by environmental adversity (such as drought, fires, floods) such as maintenance of community infrastructure and services and economic viability (especially for those communities heavily reliant on agricultural activity) (27). Farming is an occupation which exposes farming families to high levels of stress (28). This is particularly the case in times of drought; and yet rural farming communities are likely to hold attitudes towards health and wellbeing which make it difficult to seek help in times of stress (29).

The stress experienced by rural people in response to drought and extreme climate variability has been associated with increased mental health problems (30). While there is an extensive literature documenting the adverse mental health effects of acute natural disaster on young people and families (31) there is very limited research investigating the mental health consequences of drought. It is likely that the strong attachments rural people hold to the rural lifestyle and farming, and the merging of the farming occupation with identity for all family members, intensifies the distress experienced as a result of drought (32). Rates of suicide in Australian rural locations are higher than in comparable populations worldwide (33,34).

The social and psychological impact of drought on rural residents has received limited attention from research and has primarily focussed on adults rather than children. A body of drought related research by the Centre for Rural and Remote Mental Health (CRRMH) in Australia commenced with focus groups with rural adults (35) and then progressed to more quantitative studies through to the development of service enhancement models to facilitate early access to mental health care for adults engaged in farming (36). However there have been two recent studies of the mental health experiences of young adolescents living in drought in rural Australia (3,37). The two studies were conducted three years apart in the same geographic location with participants recruited from schools.

The first study sampled 334 adolescents aged 11 to 17 years from six Central Schools in the rural south west of New South Wales (NSW), Australia. Central Schools provide education from kindergarten through to the end of secondary school and typical enrolment is around 150 students. At the time of the study this rural region was part of the 80% of NSW declared to be in drought by the government. The region relies heavily on agriculture including sheep and cattle grazing, cereal crops, irrigated rice and cotton crops, vineyards and orchards with dependence on winter rainfall and irrigation storage from the Snowy Mountains Hydro Scheme. The population of the region is sparsely distributed and often long distances from regional centres where health services are located.

Surveys, including the Strengths and Difficulties Questionnaire (SDQ), were completed by the full sample of 334 adolescents, and a subgroup of 84 adolescents who were representative of the age groups also participated in focus groups. Factors identified from the focus groups were (i) family impact; (ii) loss; (iii) country lifestyle; (iv) environmental; (v) lack of control; and (vi) loss of friends. The impact on family accounted for 19% of the variance in the model and responses included “My mother never had to work before….dad gets cranky and mum gets worried” (Dean & Stain, 2007). The adolescents demonstrated they were well aware of the impact of the drought on the community with statements such as “lots of stress…there have been a couple of people drown themselves cause of the drought”. However the adolescents remained convinced of the positive aspects of rural living – “We have stronger relationships with our school teachers...we know them out of school”. In this first study, the SDQ results showed the adolescents were not experiencing distress above normative population levels for their ages.

The second study recruited 111 adolescents aged 11 to 17 years from five Central Schools in the same rural region some three years later and was focussed on the potential cumulative effect of drought on mental health as the area had remained in drought (3). The response rate of 26% for this second study reflected the unwillingness of parents to discuss the ongoing drought. In contrast to the first study, results showed the adolescents scored significantly higher on all problem scales for the SDQ compared to the Australian normative sample.

Table 1. Young peoples' self ratings on the SDQ – A comparison of Australian norms, Australian drought studies and UK trends.

Research	Emotion	Conduct	Hyperactivity	Peer Problems	Total Difficulties	Prosocial
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
Australian Norms (N = 553)	2.4 (2.0)	1.8 (1.7)	3.2 (2.3)	1.5 (1.6)	8.96 (5.62)	8.0 (1.7)
Dean & Stain, 2007 (N = 330)	2.6 (2.5)					
Dean & Stain 2009 (N = 111)	3.36 (2.46) **	2.19 (1.85) *	3.77 (2.12) *	2.23 (1.81) **	11.62 (5.94) **	7.43 (2.9) *
UK Study (Maughan et al., 2004)						
1999 (N = 4244)	2.81 (2.1)	2.23 (1.7)	3.76 (2.2)	1.48 (1.4)	10.28 (5.2)	7.99 (1.7)
2004 (N = 2930)	2.62 (2.0) ••• #	2.12 (1.17) ••	3.85 (2.2)	1.47 (1.5)##	10.07 (5.2)#	7.95 (1.7)

* $p < 0.05$
** $p < 0.01$ (for both Australian Norms and Dean & Stain, 2007)
•• $p < 0.01$ (Maughan et al., from 1999 to 2004)
••• $p < 0.001$ (Maughan et al., 2004 from 1999 to 2004)
# $p < 0.01$ (Dean & Stain, 2009 from Maughan at al., 2004)
$p < 0.0001$ (Dean & Stain, 2009 from Maughan at al., 2004)

As well as confirming the themes of the first study, the results indicated a new theme of climate change as well as greater emphasis on loss and grief. Higher levels of problematic behaviour, peer relationships, and hyperactivity were associated with drought related factors such as family concerns, financial stress, climate change, mental health impacts, and an environment where death and loss is perceived. Distress levels for older adolescents were more affected by loss of friends from the area than was the case for the younger adolescents. The adolescents showed significantly higher levels of distress and behavioural difficulties than the general population and the adolescents in the earlier research conducted in the same region. Further impacts of the ongoing drought in relation to behaviour and peer relationships are suggested. These difficulties were associated with family concerns, financial stress, climate change, mental health impacts, and an environment where death and loss is perceived.

Comparison of the SDQ results from both of these studies with the Australian normative data shows that adolescents who had experienced at least three years of continuous drought (study 2) were experiencing higher levels of distress than three years earlier and significantly higher than a comparable Australian community group. Of particular interest is the comparison to large scale UK population studies showing the Australian rural adolescents reported significantly higher levels of distress than that found in the general UK population for this age group (38). This finding supports the view that rural adolescents experience living in prolonged drought as highly stressful and therefore likely to impact on their development and mental health. Given the interweaving of farming responsibilities with family life it is likely these adolescents experience distress and worry in relation to the uncertainty and economic hardship that the drought brings to farming. Evidence as reported earlier of the degree of distress experienced by adolescents in relation to family financial problems lends support to this proposal.

ADOLESCENT WORRIES IN RELATION TO DROUGHT

The view of adolescents experiencing drought was explored further in a study targeting rural adolescents from boarding schools whose families lived in drought affected areas. It was proposed that adolescent boarders would have specific stressors in relation to the drought such that there would be perceived (i) uncertainty over the financial ability to remain at the boarding school; (ii) expectations of higher levels of academic achievement to ‘repay’ the financial stress of school attendance; and (iii) uncertainty about the reality of the drought impact on the family farm. The study sampled 45 adolescents and seven teachers from six boarding schools servicing drought affected areas across NSW.

Consistent with the findings from the studies of adolescents from Central Schools in drought affected NSW (3,37), the adolescent boarders reported drought related worries in relation to the perceived impact on health, family, finances and community (39). The adolescents reported experiencing a range of mental health problems with the added difficulty of being at a distance from family. As expected there were concerns about the financial pressure on the family and the burden of school fees as well as difficulties with family relationships. The adolescents were well aware of the impact of the drought on the community such as concern for the loss of businesses and services in the areas as families leave.

The out migration of rural families and therefore loss of friends was a common concern across all three drought studies reported here. The critical role of friends during adolescence and that of social support in ameliorating the impact of stressors on mental health suggests the loss of friends be addressed by any type of ‘intervention’ for adolescents in drought areas. It is well known that isolation is an experience for many in rural areas and that this can become heightened in adolescence (2). The adolescent boarders reported experiencing isolation in relation to long distances from friends and services, decreased social and community activities such as sport due to the drought, separation from family while at school and therefore lack of support and also information about the impact of the drought on the family and farm.

CONCLUSIONS

The literature shows that in addition to the developmental challenges of adolescence, there are rural specific stressors for adolescents in rural communities and studies of adolescents in drought affected Australian communities provide evidence of drought being yet another stressor for these adolescents. The higher rates of risky behaviour reported for rural adolescents raises further concern for the wellbeing of adolescents and highlights the urgency of addressing the needs of rural adolescents in relation to climate adversity such as drought. Recommendations from the adolescent boarders include provision of information about mental health and services, skills for coping and also to help friends in need, as well as support services provided within the school environment. The mental health impact of climate adversity on adolescents should be a major public health priority for all communities.

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Chapter 15

THE EFFECT OF CLIMATE CHANGE ON CHILDREN LIVING ON PACIFIC ISLANDS

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Climate change is projected to increase temperatures, sea level rise and extreme weather events. Children living in remote, low-lying Pacific Islands are particularly at risk from the impacts of climate change, due to their physical, environmental and socio-economic vulnerability. The objective of this paper is to examine the potential health effects of climate change and climate change related migration on children in rural and remote areas, especially those living in the Pacific Islands. A review of the literature on climate change health impacts in rural and remote areas was conducted, focusing on those living in the Pacific Islands and on climate change related migration. The results suggest climate change is likely to increase heat related and extreme weather related mortality and morbidity and increase infectious disease incidence and transmission in the Pacific Islands, especially in children. Climate change is also likely to impact indirectly on child health by affecting water, food and financial security and by increasing inequalities. By 2050, approximately 235,000 people on Kiribati, 20,000 people on Tuvalu and 800 people on Tokelau are likely to be at high risk of climate-change-related migration and the adverse impacts this can have on mental, physical and social health. Climate change is likely to have a significant impact on the health of children living in rural and remote areas, such as the Pacific Islands. It is therefore imperative that resources are targeted to enhance the adaptive capacity of these areas.

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INTRODUCTION

Small, low-lying Pacific Islands are relatively fragile ecosystems and they are particularly vulnerable to climate change (1,2). Approximately 0.1 percent of the world's population live on these islands (3,4) and this population is very youthful, with more than half of the population under the age of 24 years (3). Concerns about the potential impact of climate change, especially on sea-levels and already precarious water supplies, have reached the point where plans to vacate whole island populations within one generation have been considered (5,6). In the meantime, extreme climate events such as droughts and floods are leading to crop failures and contributing to political instability, with the result that in some islands there has been a rapid increase in families shifting into squatter towns; it is estimated that 15% of Fiji's population live in squatter camps (7).

Migration from vulnerable areas due to climate change is likely to be unavoidable and current estimates are that, globally by 2050, there will be 200 million displaced people (8). An obvious next move for Pacific populations is migration to the closest larger countries, New Zealand and Australia. Projecting potential migration patterns with certainty is difficult. However, using available information on population projections and the potential exposure, vulnerability and adaptive capacity of three selected islands, we have estimated that, by 2050, approximately 235,000 people on the Republic of Kiribati, 20,000 people on Tuvalu and 800 people on Tokelau would be at high risk of climate-change-related migration (9).

In this chapter, we review the overall projections for the major health effects of climate change on rural and remote areas, but focus where-ever possible on what we know about the potential effects on Pacific Islanders and particularly their children. We argue that changes in climate are likely to have a significant effect on the health of Pacific children, through both direct and indirect pathways. A particular focus of this chapter will be on climate change-related migration and the impact this could have on children's health.

BACKGROUND

The Intergovernmental Panel on Climate Change (IPCC) has projected that climate change will cause an increase in temperatures, sea level rise and extreme weather events (10). In the latest IPCC report, the best estimates for the increase in global average temperature range from 1.8 to 4.0 degree C by 2090, depending on the scenario, (with the likely ranges between 1.1-6.4 degree C) (10). Similarly, by 2090 the projected temperature range for the Republic of Kiribati in the Pacific is for a 1.2 to 5.6 degree C rise (11). This warmer climate is likely to have the effect of intensifying tropical cyclones, by increasing the speed of peak winds and mean as well as peak precipitation intensities and storm surges (12). These changes have critical implications for children in Pacific Island states.

Sea level rises have most recently been predicted by Rahmstorf (13) to be between 0.55m and 1.25m by 2100, (0.50m to 1.40m with statistical error) and by Horten et al.(14) to be between 0.54m and 0.89m by 2100, (0.47 m to 1.0m with statistical error). However, there is still considerable uncertainty regarding the likely upper limits for sea level rise this century. Coastal erosion and land subsistence are likely to be accelerated due to storm surges and sea level rise (12). One of the potential extreme impacts of sea level rise would be the complete inundation of an island. The majority of the land in Pacific atolls such as Kiribati, Tokelau and Tuvalu is only 4m above sea-level. Consequently, these remote islands are likely to be particularly vulnerable to the impacts of sea level rise.

While, the distinction between urban and rural areas is not always clear, there are no internationally recognised standard definitions (15,16). For statistical purposes rural areas are often defined by exclusion; that is they are defined as rural because they do not have the population size or density to be classified as urban areas (15,17). However, there is significant diversity within the rural areas classified in this manner (18). Consequently, areas are also sometimes further classified using other factors, such as by the characteristics of the area or the extent of dependence on urban areas for work (15,19). Here, we use the terms rural and remote to refer to areas with relatively low population density and size. This definition includes areas that are more reliant on climate sensitive occupations such as agriculture and those that are geographically distant from highly populated major urban centres. Small islands states in the South Pacific are sentinel cases.

CLIMATE CHANGE PROJECTIONS

The IPCC has made several climate change projections that are likely to impact on rural and remote areas. These include an increase in global average surface temperature, sea level rise and an increase in the frequency and intensity of extreme weather events such as floods, storms and droughts (10). The IPCC has also projected that there will be changes in precipitation patterns, with an increase in precipitation in high latitude areas and a decrease in low latitude areas (10). Additionally, the combination of increased temperatures and ocean acidification due to climate change is likely to increase coral bleaching, which could have a significant impact on remote coastal and island communities (20). These changes are all projected to lead to a dramatic reduction in biodiversity (10). However, the extent of their impact on the community is likely to be influenced by other factors such as susceptibility, exposure, adaptive capacity, population growth, resilience, strategic adaptation measures and the level and rate of change in emissions.

SUSCEPTIBILITY

There are several reasons why children living in rural and remote areas may be more susceptible to the impacts of climate change. As stated in the recently commissioned Lancet article on climate change, “because climate change acts mostly as an amplifier of existing risks to health, poor and disadvantaged people will experience greater increments in disease burden than rich less vulnerable populations ”(21). Those living in more rural and remote areas have been found to have on average higher mortality rates and a higher prevalence of chronic diseases compared to those living in urban areas (22,23). Infant mortality rates are much higher in remote small islands like Kiribati (52 per 1000 live births in 2005) and Tuvalu (21.6 per 1000 live births in 2003), than New Zealand where the rate was only 4.8 in 2006 (24). Life expectancy at birth for males living in New Zealand has been estimated to be 78 years (2005-7) whereas in Kiribati it was estimated to be 58.9 (2008 estimate) (24).

These inequitable health outcomes have been attributed to the association of rurality and remoteness with deprivation, as deprivation is associated with poorer health outcomes (23). Poorer rural health outcomes have also been attributed to these areas having less access to preventative and treatment health care. A recent WHO review has identified that "approximately one half of the global population lives in rural areas, but these areas are served by only 38% of the total nursing workforce and by less than a quarter of the total physicians' workforce"(25). Consequently, both the direct and indirect impacts of climate change on health are likely to be amplified in children living in rural and remote areas. These potential impacts will now be discussed in more detail.

DIRECT HEALTH IMPACTS

The projected increases in temperature, heat waves and extreme high temperatures could have considerable implications for children living in rural and remote areas. In South East Asia, heat waves have been found to be associated with high mortality in rural populations (26,27). High temperatures have been found to be particularly associated with an increase in heat-related mortality and morbidity for elderly (28) and it has been postulated that young children may also be vulnerable because, like the elderly, their heat regulating mechanisms tend to be less effective and they tend to be less able to access or request fluids themselves when needed (29), although a recent review of heat waves in Europe did not find a risk of mortality attributable to heat waves for children (28).

Those living in rural and remote areas are less likely to be subjected to the "heat island" effect found in urban areas, whereby urban areas retain more heat throughout the night and consequently increase thermal stress (29). Additionally those living on islands may have the temperatures moderated by sea breezes. However, in some Pacific Island states there has been a move away from more traditional housing to housing styles that are less suitable to the climate, which may increase the risk of thermal stress (12). Also heat-related mortality and morbidity may be exacerbated by factors such as lack of socioeconomic resources, lack of access to air-conditioning, reduced access to timely medical attention and social isolation (29,30). Likewise, respiratory illnesses may be exacerbated by the effect of increased temperature on aeroallergens and air pollutants from photochemical smog (31).

Prolonged higher temperatures are also associated with an increased risk of wild fires, wood ash and dust storms (10) and consequently an increase in fire-related mortality, severe burns, injuries and respiratory illness (27). The health impact of fire in rural and remote locations is likely to be exacerbated by the difficulties in accessing these areas to assist those affected. Those living in rural areas and children, especially those under the age of five (32) have been found to be at increased risk of fire-related injury and death. Therefore, it is likely that an increase in fire due to climate change would compound this risk.

The projected increase in the frequency and intensity of extreme weather events due to climate change is also likely to directly impact on the health of children in rural and remote areas. Extreme weather events, such as floods, have been associated with an increase in drowning and physical injuries. These events have also been associated with an increase in suicide and other mental health issues and children have been found to "exhibit more severe distress after disasters than do adults"(27,33).

The incidence and transmission of certain infectious diseases are projected to increase due to climate change, which is likely to affect the health of children living in rural and remote locations such as the Pacific Islands. Currently diarrhoeal illnesses are a leading cause of mortality and morbidity in children in developing countries (34). A study of diarrhoeal disease in the Pacific found a positive association between the incidence of diarrhoeal disease and average annual temperature (35). Additionally extremely low and extremely high levels of rainfall have been linked with an increase in diarrhoeal diseases in the Pacific, which has been attributed to their effect on water supply quality and sanitation (35). Consequently, climate change is likely to increase diarrhoeal illness in this region. Ciguatera fish poisoning is also likely to increase as temperature increases, as warmer sea-surface temperatures have been found to be associated with increases in ciguatera outbreaks in the Pacific (36).

Climate change models have predicted that, due to climate change, the incidence of certain vector borne diseases is likely to increase, as higher average temperatures can increase the rate of pathogen maturation and replication within mosquitoes (21). Predictions are that in Kiribati, for example, the incidence of dengue fever could increase by 22-33% due to climate change (37). Malaria is another vector-borne disease that could increase in incidence due to climate change (12). The significant impact that malaria can have on island populations has been demonstrated in the Solomon Islands, where malaria is one of the leading causes of morbidity (38). The geographic range for these vector-borne diseases is also likely to increase as temperatures rise. Those living in areas that have previously been unaffected by these vector-borne diseases, especially children, are unlikely to have immunity and will therefore be at increased risk of infection.

INDIRECT HEALTH IMPACTS

Climate change has the potential to also have a significant indirect impact on the health of children in rural and remote areas. For instance, access to clean water is vital for health and climate change is projected to affect water security in many rural and remote regions (10). Many Pacific Island states are highly dependent on climate sensitive water supplies, such as groundwater wells that tap the island's fresh-water lens and rainwater collection tanks (12). Consequently, they tend to already have significant issues with water security. This problem is likely to be exacerbated by climate change altering precipitation patterns, increasing droughts and causing salination of the water supply through sea level rise.

Sanitation systems also tend to be less secure in Pacific Islands. In Kiribati an inadequate sewage system has led to effluent collecting in coastal waters.(6) Consequently, water supplies are at greater risk of contamination during extreme weather events. Additionally, if there is an increase in the frequency and intensity of droughts then less water may be used for hygienic purposes, increasing the risk of enteric disease.

Those living in rural and remote areas tend to be more reliant on climate sensitive food supplies, such as from fishing and subsistence agriculture (12). This increases the vulnerability of their food supply to climate change, as agricultural productivity is likely to be adversely affected by increased water insecurity, damage from extreme weather events, spread of temperature sensitive pests and salination of the soil due to sea level rise (39). Fishing is also likely to be adversely affected by climate change, due to the projected reduction in biodiversity, the increase in coral bleaching and a potential migratory shift in vital fish resources, such as tuna (12). Importing food, especially to remote island locations, is expensive and difficult to sustain in locations with limited financial resources. Therefore climate change is likely to increase malnutrition in rural and remote areas (10). This would have a significant impact on child health, the World Health Organisation (WHO) has estimated that malnutrition currently contributes to greater than a third of all child deaths (34). Additionally, children that are severely malnourished are more vulnerable to illness and their growth and development can be adversely affected (27,34).

The projected increase in the frequency and intensity of extreme weather events due to climate change could have a significant impact on the social determinants of health, such as employment and housing. Those living in rural and remote locations are more likely to be involved in occupations that are climate sensitive, such as agriculture or tourism (12). Consequently, changes in climate, such as the projected increase in extreme weather events, are more likely to significantly impact on their main source of income. Children are usually dependent on others for basic health necessities such as food, security, water and shelter. Therefore, they are likely to be adversely affected by any impact on their parent's or guardian's resources to care for them.

Floods and storm damage can decrease the quality and healthiness of houses by enhancing mould growth (40). The move towards more westernized housing in the islands could increase the damage caused by these extreme events, as these designs may be less resistant and slower to repair (12). Due to an increase in frequency of extreme events, the likelihood of being able to obtain insurance could also be affected, increasing vulnerability to the impact of further storms and floods (41).

Extreme weather events could cause damage to vital public health infrastructure, reducing access to clean water supplies and sanitation and thereby increasing the risk of infectious diseases spreading (21). Access to medical attention, food and electricity supplies could also be blocked by extreme weather events in rural and remote areas, thereby reducing aid available for those children in need. For example, in a recent cyclone, the hospital in Niue was totally destroyed for the second time (42). The recovery from such events can take years before services are fully restored. If these events become more intense and frequent the population may not have had time to recover from the previous event, hence escalating their vulnerability (12).

Sea level rise could also affect the social determinants of health as, especially on remote small low lying islands, the amount of available land could be reduced. This combined with population pressure could lead to overcrowding and an increase in poor quality housing on marginal land. Additionally, it could reduce the amount of land available for agricultural development, affecting income and food security (12). An analysis of the overall situation by the World Bank has estimated that due to climate change it is likely that there will be an absolute loss of 17-34% of current GDP by 2050 in Kiribati (43). This is significant as Kiribati already has one of the highest poverty rates in the Pacific (6).

There is a clear relationship between inequalities and health and climate change is projected to increase inequalities both within countries and between countries (21). Many rural and remote communities are vulnerable to the impacts of climate change, because they are located in environmentally marginal or isolated areas and lack the resources, infrastructure, governance and adaptive capacity to respond (44). These countries and regions typically have contributed the least to global greenhouse gas emissions, however the children living in these areas are more likely to be affected by climate change.

Figure 1. Tidal floodwaters in Tuvalu. Source Oxfam, 2009 (1).

CLIMATE CHANGE RELATED MIGRATION

Some regions or areas will be affected by climate change more than others due to their physical, environmental and socio-economic vulnerability. Consequently, one of the projected impacts of climate change is that there will be an increase in climate change related migration (10). Climate change related migration is a term that refers, in this article, to migration that is due in part to the impact of climate change. In the past the term “climate refugees” has been applied to people affected by climate change in this manner (45). However, there is concern that the use of the term “refugees”, to refer to those displaced by climate change, could “depoliticise the causes of displacement, so enabling states to derogate their obligation to provide asylum” for political refugees (46).

Quantifying the potential for global climate change related migration is hampered by uncertainties in projecting the impacts of climate change, by the complex, interdependent drivers of migration and by the lack of direct evidence attributing migration specifically to changes in climate (8,10). However, it has been estimated that potentially 200 million people may be displaced by climate change by 2050 (47) and there is growing international concern regarding the impact that this could have on health and well-being (48).

This issue is significant for rural and remote areas, as many of these areas are at increased risk of climate change related migration. For example Kiribati, Tuvalu and Tokelau are small remote islands in the South Pacific that are extremely vulnerable to the impacts of climate change, due to their size, low elevation above sea level, current population pressures and limited resources. As discussed above, the projected sea level rise, temperature increases, changes in rainfall patterns and increases in the intensity and frequency of extreme weather events are likely to increase infectious diseases and food, water and financial insecurity in these islands (12). These factors, combined with other social and economic drivers are likely to increase migration and potentially could lead to permanent displacement of the population.

The children from rural or remote areas that consequently migrate with their families, are at increased risk of certain health issues. For example, in their new location their families may have difficulty accessing healthy housing, employment, education and health care due to language and cultural barriers (49). Where children have come from subsistence living, the move to relatively large cities, where most migrants are likely to re-locate can be traumatic (50). The traditional patterns of chain migration can mean that families often live for long periods with their extended families in conventional houses that have been designed for nuclear families (51). While extended-family living can help to maintain customs and language in the new country, families can still be culturally and socially isolated from the loss of their extended social networks. Moreover, extended family living can lead to household crowding that leads to dramatically increased rates of close-contact infectious diseases in children such as meningococcal disease (52) and tuberculosis (53).

The permanent loss of a nation state due to climate change has not yet occurred and so the effects that this might have on the health of the population have not yet been studied. However, the impact of permanently losing a homeland could be likened to the experience of indigenous populations who have been displaced from their land due to colonisation. In New Zealand there is a difference in life-expectancy between the indigenous Māori population and non-Māori even after controlling for deprivation (54). This inequity has been linked to the impact of colonisation and loss of land (55). Kunitz (56) has also shown in a study of indigenous people, who have been colonised, that historical loss of land has a significant effect on cultural resilience and the health status of displaced peoples.

If migration is delayed until relocation is urgent, then the vulnerability of those displaced is likely to be increased. Previous periods of rapid unplanned urbanization have had considerable health impacts, particularly for indigenous populations. Unplanned urbanization can lead to slums forming on the outskirts of cities, population pressure, poor sanitation and water supplies, overcrowding and an increase in infectious diseases and susceptibility to heat waves and extreme weather events. Conflict can also arise due to an increase in migration with the resident population feeling threatened (49).

The children of those who remain in rural and remote locations may also be affected by the displacement of family and friends due to climate change, as vital support, skills and leadership may be lost from the community. Those left behind tend to be those without resources to migrate or the more elderly and weak. Consequently, those who remain living in these remote and rural locations may become even more vulnerable to the impacts of climate change (49).

PLANNING FOR CLIMATE CHANGE RELATED MIGRATION

As well as taking action to mitigate climate change and assist rural and remote communities in building adaptive capacity, it is also crucial that inter-agency planning for climate change related migration begins at a central and community level for housing, education and other infrastructure. This is particularly important for countries such as New Zealand and Australia, which are likely to be the preferred destinations of Pacific migrants, due to their relatively close proximity and the cultural, historical and colonial ties. This would help to avoid the possible negative effects of unplanned migration, particularly for children (9).

However, recent qualitative work interviewing key informants in New Zealand with designated responsibilities for settling migrants has shown that there were some barriers to further developing adaptive capacity within these services (9). Building adaptive capacity, to specifically address the potential for climate change related migration, was not perceived by some of the providers as a priority, which implies they would be less likely to take action to address this issue. Additionally, it was perceived that adaptive capacity was "constrained" and restricted by current limitations on resources and a lack of awareness of the issues within external planning and funding agencies. These findings imply that to facilitate the development of adaptive capacity within these vital services, there is a need to improve awareness and knowledge, in both providers and external agencies, of the implications of climate change related migration and the importance of building adaptive capacity.

CONCLUSIONS

In conclusion, climate change is likely to have a significant impact on the health of children living in rural and remote areas, such as the Pacific Islands. The projected increase in temperature, sea level rise and increase in the frequency and intensity of extreme weather events could directly impact on their health by increasing heat-related and extreme weather-related mortality and morbidity and increasing infectious disease incidence and transmission. Projected climate changes are also likely to have indirect impacts on health by affecting water, food and financial security and thereby increasing social and economic inequalities.

Many people living in the Pacific Islands could eventually be displaced by climate change, which could adversely affect both the health of those children displaced and the children left behind. Children living in these remote and rural communities have contributed very little to creating the issue of climate change, yet their health is likely to be significantly affected. It is therefore imperative that resources are targeted to reduce the vulnerability of this group to the major adaptive changes they will have to make in their life-times. Such efforts should focus on the resiliency of the families and communities as a way of protecting and supporting the children.

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Chapter 16

FROM TYPHOID TO TSUNAMIS: SAMOAN CHILDREN IN A CHANGING WORLD

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Samoa consists of two main islands, has a tropical climate and is located in the Southwest Pacific. The objectives of this paper are to give an overview of climate change in Samoa; outline what health means from the Samoan perspective as this is important when discussing the possible impacts on child health from climate change; discuss adaptation and mitigation initiatives and potential implications for child health. We will use a case study of the devastating 2009 Tsunami to outline impacts of natural disaster on child health in rural areas. While climate change is likely to bring new challenges to Samoan children, many of the problems that are projected to affect Samoa's children such as diarrhoeal illnesses, water insecurity and dengue fever are already on hand. However, they do have the potential to be exacerbated in a changing world. Adaptation in many areas is already underway in Samoa, but much remains to be done. Little is known about aspects that affect rural children in particular, although that they are likely to be more susceptible to water insecurity, cyclones and other extreme coastal events. Baseline data on health conditions has been identified as an area that needs strengthening as part of adaptation measures.

INTRODUCTION

Just as the extent and nature of climate change is expected to vary markedly by region, country and even within countries, the impacts of climate change on the health will depend very much on the local context. Impacts on child health may be relatively minimal for some developed, well resourced countries while potentially devastating in areas in the world that

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are likely to bear the brunt of the effects of climate change, such as parts of Africa, Asia and the Pacific, including Samoa (1-5).

Even within Samoa itself, the impacts on child health are likely to vary depending on location, including rural versus urban differences, as well as on the vulnerability, resilience and adaptive capacity of particular people, families, communities, organisations, government structures and environments.

In this paper we will give an overview of the climate changes that have occurred in Samoa and what might be expected in the future; outline what health means from the Samoan perspective as this is important when discussing the possible impacts on child health in Samoa from climate change; the importance of resilience and adaptation to climate change, including discussion of the Samoa National Adaptation Programme of Action (NAPA) on climate change (6) and potential implications for child health.

As well as the inequities in the impacts of climate change, the impacts on child health from climate-related events may well be quite unexpected. We will use a case study of the devastating tsunami that occurred in September 2009 to outline impacts on child health in the affected rural areas. The reasons are two-fold: this event has parallels with other disasters and disaster response, particularly regarding cyclones to which Samoa is vulnerable; and secondly, there is increasing evidence that climate events and seismic activity may be linked, an unexpected development and worthy of review. This has obvious potential implications for Samoa and other coastal areas elsewhere in the world. Also, somewhat unexpected was the degree of mental stress in children and families post the disaster.

Samoa is active in measures to reduce emissions, both locally and internationally. These initiatives will be briefly discussed as well as their potential co-benefits for health.

The distinctions between rural and urban child health in Samoa are somewhat blurred as all children are potentially affected by the major challenges that climate-related events pose. Specific information on the impacts on child health in Samoa from climate events is somewhat limited, let alone from rural versus urban perspectives. That said, rural children are likely to be more affected by issues such as water insecurity and disasters. We will make specific comment on rural aspects where appropriate.

Box 1. Background on Samoa.

Samoa is located in the Southwest Pacific about 13 degrees south of the Equator. Neighbouring countries include American Samoa to the east, Tonga to the south, Tokelau to the north and Fiji to the southwest. The population was about 180,0000 in 2006, mostly settled on two major volcanic islands – Upolu and Savaii. Apia is the capital, with approximately 20% of the population. Samoa's climate is characterised by distinct Wet and Warm (November-April) and Dry and Cool (May-October) seasons; a high rainfall and humidity; temperatures usually 24-32 deg C; south-easterly trade winds; tropical cyclones during the Southern Hemisphere summer; a long dry season and vulnerability to droughts during El Niño Southern Oscillation events. The mountainous interior of the main islands has a major effect on rainfall distribution within Samoa. The main export commodities are coconut oil, coconut cream, bananas, taro, kava and fish. Manufacturing, construction, commerce, transport and communication activities, tourism, foreign aid and remittances are also significant contributors to the economy (10,12).

CLIMATE CHANGE IN SAMOA AND THE POSSIBLE FUTURE

It is important to note recent work on emissions, climate trends, and emerging impacts indicates that the Intergovernmental Panel on Climate Change (IPCC) 2007 projections may have been relatively conservative (7). For example, loss of Arctic sea ice is occurring even more rapidly than the worst case scenarios in the IPCC 4th Assessment Report (8) and global sea-level rise could be in the order of 1 metre or even more by 2100 (9). Much of the information that follows is from the 2007 Samoa Climate Risk Profile (10), which may now be conservative.

Temperature trends

Over the last century or so, the mean temperature in Samoa has increased by approximately 0.6 deg. C (6). In contrast to the predicted marked increases in temperatures over the 21st century in certain parts of the world (such as the Arctic and Africa), the increase in temperature is likely to be much less in Samoa, even in a potential “4 degrees and beyond” world by 2100 (11). Samoa’s temperatures are usually in the 24-32 deg. C range, with the frequency of 33-36 deg. C days expected to increase (10).

Sea-level rise

The observed long-term increase in sea level in Samoa has been about 5 mm a year (10). Occasional extreme high sea-level events are already associated with flooding, increased coastal erosion and salinisation of groundwater. These events are anticipated to increase in frequency (10).

Storms andcCyclones

Small island states such as Samoa are particularly vulnerable to weather extremes. The worst cyclones to hit Samoa in recent times were Ofa in 1990 and Val in 1991, together causing damage estimated at four times Samoa’s annual GDP and over 20 fatalities (6). There is the possibility of more persistent and destructive cyclones with climate change as ocean temperatures warm (1). Tropical storm and cyclone activity are influenced by the El Niño Southern Oscillation (ENSO or El Niño) and La Niña events (1).

Reefs and fisheries

Ocean warming, ENSO events and increased acidity due to rising levels of CO2, will further stress coral reefs, and is expected to cause re-distribution of fish stocks (1). Reefs are also under threat by the intense waves of cyclones and storms which have at times have severely damaged coral reefs in Samoa (6).

Rainfall, extreme rainfall events, drought and the el niño southern oscillation (ENSO)

Annual rainfall is about 3000 mm and falls mainly during the wet season (12). Samoa is prone to periods of heavy rain as well as to extreme rainfall events during storms and cyclones. No significant long-term trends in rainfall have been observed. There are large uncertainties in the rainfall projections with models indicating either increases or decrease in future mean rainfall. Climate change may increase the frequency of extreme daily rainfall events, but again there are large uncertainties (10).

Samoa is also prone to drought with some rural areas more susceptible than others. While ENSO events are associated with drought in Samoa, it is not yet clear what the future nature of these events will be (10). The long-term ENSO trends will be of considerable importance given the relationship between ENSO and such factors as rainfall, sea level and sea temperatures changes (concerns over coral bleaching, cyclone paths and intensity) and maybe even increased earthquakes and tsunami risk (see below).

Links between climate events, and volcanic activity, earthquakes and tsunamis

Evidence has been building on potential links between these seemingly unrelated events. Seismic plates and volcanoes appear to be much more sensitive than previously thought. Even slight changes in weather and climatic conditions may have the potential to trigger extreme events such as earthquakes. Relatively small changes in rainfall have been associated with increased volcanic seismic activity (13). Very small rises and falls in sea level have been linked with seismic events. For example, the arrival of El Niño has correlated with a greater frequency of small underwater quakes in the tectonic plate near Easter Island. Researchers believe that the El Niño induced rise in local sea level by a few tens of centimetres puts extra weight on the plate (14). It is also possible that thinning of glacier ice sheets will reduce weight on plates and trigger an increase in volcanic eruptions (15). The relationship between climatic events and seismic activity is still somewhat unclear and requires further work. If these seismic events do increase with climate change, then Samoa and many other low lying small island states will be especially vulnerable.

WHAT IS HEALTH FROM A SAMOAN PERSPECTIVE?

It is important to discuss what is actually meant by "health" in the Samoan and Pacific context as this will help in the understanding of possible impacts on child health from climate-related events. Different models have been developed to describe health from a Pacific perspective, each with common elements. The Fonofale Model developed by Fuimaono Karl Pulotu-Endemann is one such model and incorporates the values and beliefs that many Samoans as well as Cook Islanders, Tongans, Niueans, Tokelauans and Fijians hold (16). This Model (see figure 1) uses the metaphor of a Samoan house to outline the key elements – the floor (family), four posts (physical; spiritual; mental; and other dimensions, such as socioeconomic status and age) and the roof (culture), encapsulated in a circle to promote the philosophy of holism and continuity. These are influenced by the concepts of time, context and the environment. All aspects are dynamic and interdependent. For further explanation of the Model as well as other Pacific health and health promotion models, please see the resources available at the Health Promotion Forum of New Zealand website (17).

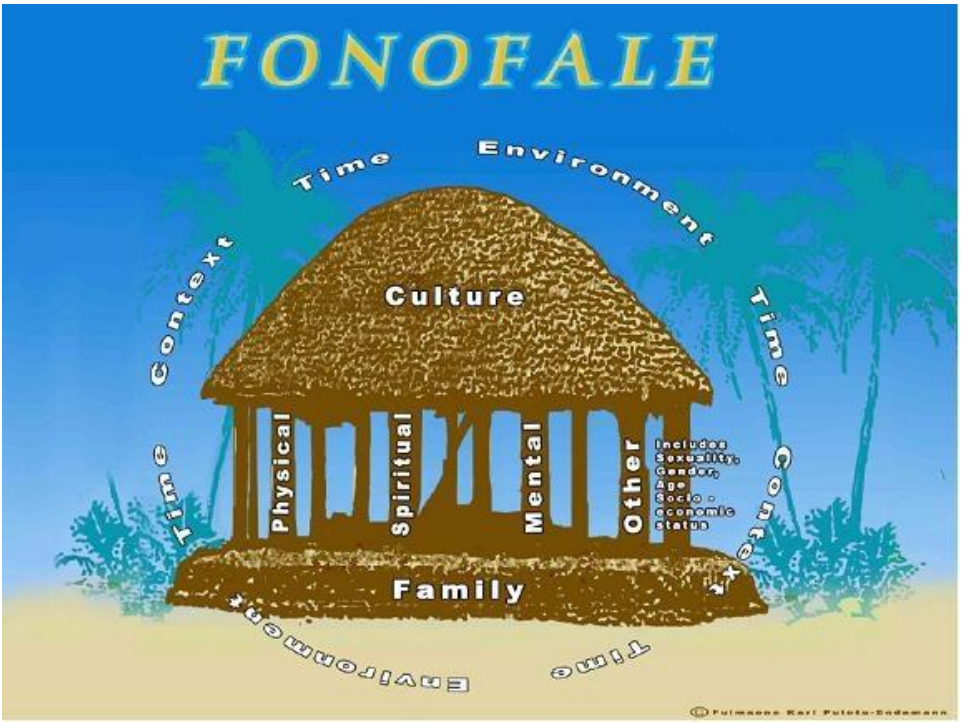

Figure 1. Fonofale model of health developed by Fuimaono Karl Pulotu-Endemann (16) Figure reproduced with permission.

SUMMARY OF THE POTENTIAL IMPACTS ON CHILD HEALTH IN SAMOA FROM CLIMATE CHANGE

We have adapted the Fonofale Model of Health as a way to summarise the potential links between climate change and rural child health in the Samoan context (see figure 2). This adaptation also incorporates elements from McMichael and Woodruff's work (18) as well as the concepts of vulnerability and resilience to climate change; adaptive capacity and adaptation to cope with the effects of climate change; and inequity, which infuses all aspects of climate change whether it be causation, vulnerability, adaptation or mitigation responses (reduction in greenhouse gas levels). Like the Fonofale Model, these concepts are dynamic and interdependent; and apply to human health as well as to the environment. The Fonofale Model and impacts on child health are also outlined in the case study of the 2009 Tsunami that affected several rural coastal areas Samoa, as well as American Samoa and parts of Tonga.

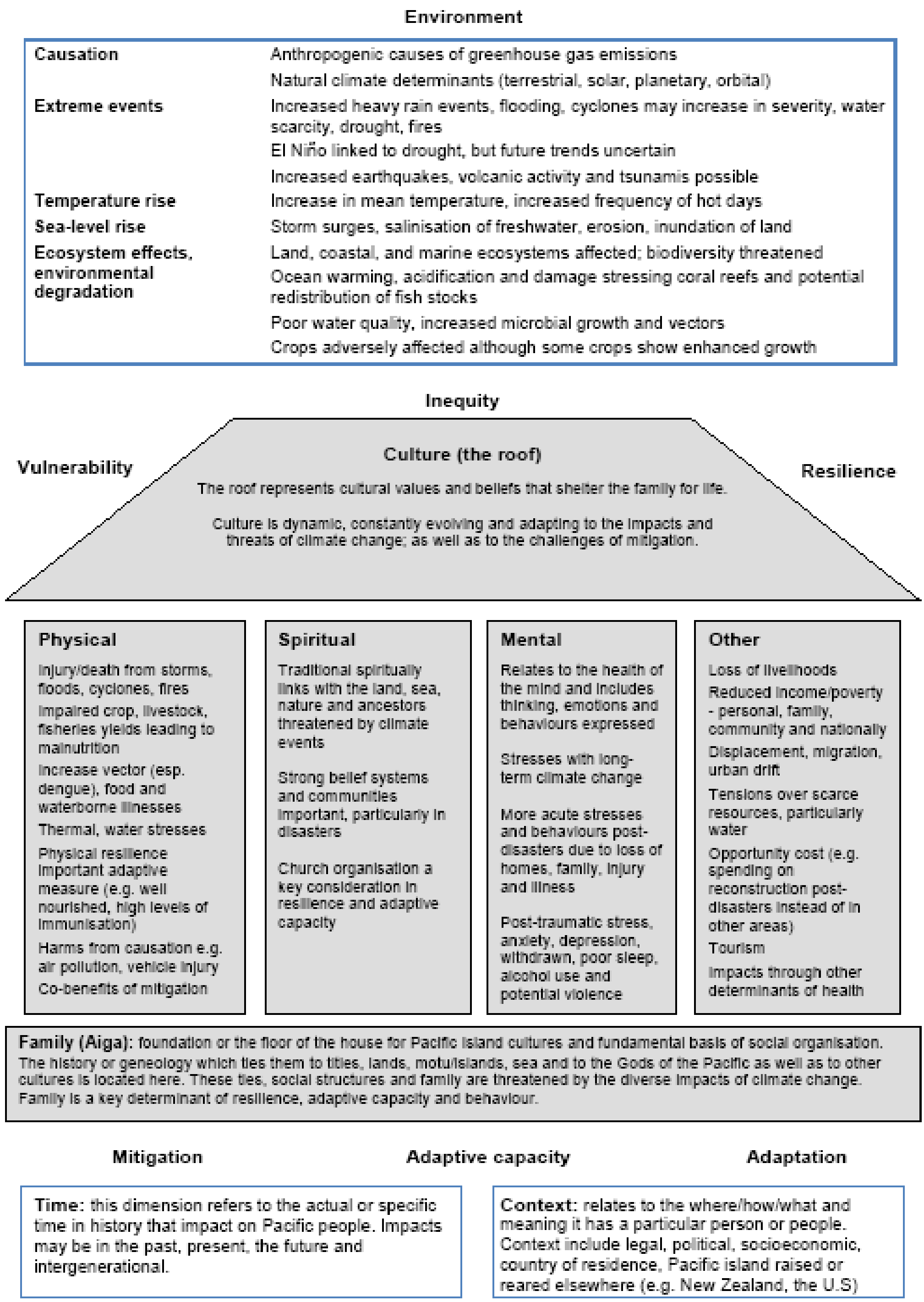

Figure 2. Adaptation of the Fonofale model of health to describe the linkages between climate change and rural child health in Samoa.

Box 2. Case study - Children in the 2009 Samoan Tsunami Disaster.

On the morning of the 29th of September 2009, Samoa was hit by the Tsunami. Over 4500 people on the Southeast coast of Upolu and Manono Islands were directly affected. The official death toll stands at 143 with 5 still missing and 310 injured. Children made up a large number of the dead in Samoa and others experienced considerable associated physical, social and emotional morbidity. In the first few days following the Tsunami, issues addressed included communication, finding survivors, clearing roads, triage and treatment of acute injuries, identification and storage of the dead, and provision of food, water and temporary shelter for survivors. The Samoan National Health Service (NHS) provided all emergency health care in the first day or so after the Tsunami until overseas aid and armed forces arrived. As well as acute care at the National Hospital and small district hospitals the NHS also had mobile doctor and nurse teams in the disaster area along with Police, Fire Service and Government workers within hours of the Tsunami. Primary health care teams were set up at the end of the first week, providing ongoing care in the district hospitals with continuing mobile outreach teams. Locating and treating displaced families and children required this outreach capacity as large numbers of families lost their homes and relocated to temporary camps in the bush and plantations. It also required local knowledge of the area and culture. Teams consulted with Pulinuu (Village Mayors) or Faifeau (Church Ministers) to find where families were and who was most in need of assistance.

The three key aspects of the public health response were:

a). Rapid assessment and response: water, food, latrines, soap, waste disposal, shelter, mosquito nets, safety (protective gear, wound care and tetanus vaccination)

b). Enhanced surveillance of priority diseases by syndrome: acute rash and fever (concern over possible measles, dengue), diarrhoea, jaundice (hepatitis), respiratory infections and tetanus

c). Health Promotion and Protection in the community: mobile clinics, mosquito control advice, hygiene, health promotion, measles vaccination and mental health (community-based resilience model).

Pulotu-Endemann's Fononfale Model for Samoan health (see article for details) is a useful way to capture the enormity of the 2009 Tsunami's effect on children in Samoa. This Model depicts health as having physical, mental, spiritual and other dimensions with a foundation of family and supportive overarching culture. Their environment was devastated with immediate loss of their villages and homes followed by weeks of clean up and the need to shift to new temporary housing of tarpaulins or tents. The physical child health issues faced included near-drowning, soft tissue and orthopaedic injuries, and aspiration pneumonia directly as a result of the Tsunami wave. In the weeks following, children experienced skin and respiratory tract infections, gastroenteritis, and new injuries or presented late as a result of displacement from their usual homes and support systems, or poor living conditions. Child Tsunami survivors also experienced mental health problems due to loss of homes and family members, physical injury and illnesses. Problems included post-traumatic stress disorder symptoms, poor sleep, anxiety and depression. Parents, teachers and clinicians reported children were unusually quiet and "clingy" following the Tsunami. Many children and adults remain too frightened and traumatised to return to coastal areas and plan to permanently re-build on higher ground rather than return to their traditional coastal village sites. In addition, the previous immediate and close relationship with the sea changed physically and potentially may have changed emotionally and spiritually for Samoan children and families. The spiritual dimension was observed to be strong and supportive for Samoan children and their families. Strong Christian belief systems and the maintenance of Church organisation was a notable support to families. Local Faifeau were pivotal in identifying families in need and assisting with mental health and emotional trauma following the Tsunami. The "other dimension" of health included loss of family livelihood, reduced income and loss of usual resources such as neighbours and village life. The foundation of health in Pulotu-Endemann's Fonofale Model is the Aiga or family. Following the Tsunami, children lost family members and surviving family were displaced from their land beside the sea. This displacement for Samoans is far more than housing. The land is also identity, belonging, and connection with ancestors. Family titles, rituals and stories are linked to their land. Re-building for families in the context of this displacement is difficult to contemplate. What was observed following the Tsunami, however, is the strength of Aiga with family both in Samoa and from overseas coming together to face this new challenge. Culture is the protective roof in the Fonofale Model and as with Aiga, the presence and endurance of strong cultural beliefs, structures and systems seemed to be a positive support to children following the Tsunami. The Fonofale Model is able to portray the complex effect of the Tsunami on children in Samoa; in particular, it enables the dimension of time, context and surrounding environment to be considered. While the long-term effects of wounds, injury and chronic lung disease following pneumonia in children can be anticipated, what is uncertain are the long-term effects arising following displacement and the changing relationship with the sea. What is reassuring in Samoa is the strength of Aiga, spirituality and culture, which will hopefully enable surviving children to have the best possible outcomes following the Tsunami.

Note: Teuila Percival was involved in paediatric care as part of the Tsunami response and in subsequent follow-up visits

Figure 3. Tsunami devastation at Lalomanu, Southeast coast of Upolu. Photo: Teuila Percival, Oct. 2009.

CHILD HEALTH IMPACTS FROM CLIMATE-RELATED EVENTS AND ADAPTATION TO CLIMATE CHANGE

Key health concerns are water and food-borne diarrhoeal diseases; vector-borne diseases, in particular, dengue fever; food insecurity and nutrition; and death, injury and conditions related to extreme events such as cyclones and flooding. There are also many potential indirect effects from climate change on the health of children and their families such as via poverty, loss of livelihoods, and altered cultural and social identity from the loss of land and biodiversity.

Community consultation has led to development of the National Adaptation Programme of Action (NAPA) which is guiding cross-sector climate change adaptation initiatives in Samoa (6). The NAPA has actions in several areas that aim to improve the resilience of families, communities, the environment, infrastructure, the health and other government sectors, and the economy – all of which have direct and indirect influence on the health of children in Samoa. The NAPA is being progressively implemented, for example, in the agriculture and health sectors.

The health sector vulnerability and adaptation assessment report (19) identified that vulnerabilities are expected to increase with climate change unless effective adaptation measures are adopted. Particular areas identified for strengthening include baseline data, monitoring and surveillance, early response systems, sustainable prevention and control systems, as well as intersectoral, regional and international cooperation. As part of adaptive capacity it will be important to understand the environmental and human factors associated with climate-related conditions.

We will now outline several key areas with regards to child health and some adaptation initiatives that are planned or are being implemented.

Agriculture and food security

Plantations and livestock are a major contributor to rural semi-subsubsistence living in Samoa. Coconut and taro (the country's primary staple food) are the major cash crops. There is some dependence on imported foods. Together, agriculture, forestry and fishing generates around 20% of GDP (6).

Agriculture is particularly vulnerable to adverse events. Widespread damage causes great losses to subsistence and commercial farmers and threatens livelihoods as well as food security, food prices and nutrition for all Samoans. Crops are damaged or devastated by high winds, storm surges in coastal areas, flooding and fires. Water for agriculture is an issue during droughts. Fish species potentially may migrate in response to climate change. High winds have been linked to the spreading of taro leaf blight spores which devastated the taro crop in the early 1990s and reduced taro exports for a period to almost nil. Bananas, another staple crop, have been identified as having a low tolerance to climate hazards (6).

However, there are some potential benefits with changing climates. Samoa has seen its seasons change, with mangoes having two crops a year and breadfruit now available all year.

The Ministry of Agriculture is leading adaptation with regards to improving agriculture and food security. Initiatives include the development of drought, flood, salt and disease resistant versions of existing crops as well as trialling of new crops. Alternative farming methods are being explored in order to improve productivity and protection of soil and water resources. Community resilience has also been improved through the stockpiling of food by certain churches, which has proved invaluable post-cyclones. Other priority areas for adaptation activities include forest fire prevention, forest rehabilitation and reforestation as ways to protect biodiversity, cultural values and land from erosion, as well as to provide a carbon sink and sustainable forest resources for use by communities.

Water security

The NAPA identified water resources as the major issue for rural communities (6). Samoa is already prone to dry periods and droughts, particularly during ENSO events. The effects of water insecurity are likely to affecting rural child health in potentially diverse ways such as impacts on hygiene and food safety, agriculture, fire control and livelihoods. Previous droughts have led to electricity shortages from reduced hydroelectric power generation. Critical water infrastructure is very also susceptible during extreme events such as cyclones and flash flooding. Sea-level rise increases the likelihood of salinisation of freshwater supplies.

There have also been tensions over water access and rights in rural areas (12,20). Villages have sometimes not wished to supply water to neighbouring villages suffering from water shortages; some families lacking the ability to contribute financially have been excluded from access to rural community water supplies, necessitating support from the Samoan Red Cross in order to gain access.

As part of initiatives to adapt to the impacts of climate change and variability, the Samoan Water Authority is leading the implementation of the "Securing community water resources project" which aims to improve water quality; ensure easily accessible water supply to all citizens; and ensure sustainable water supply in all communities (for at least 3-6 months in drought periods), particularly those most in need and facing hardship due to water-related problems (6). Current or planned actions include development of integrated watershed management programmes and development of alternative water storage and water efficiency technology and programmes.

Vector-borne diseases

Vector-borne diseases have the potential to increase their range and impact if Samoa experiences increased temperatures, heavy rain events, flooding, sea-level rise as well increased breeding locations resulting from storm and cyclone damage. Drought may also have a potential impact if vectors such as mosquitoes multiply in water supplies near homes and villages (2). Samoa already has high levels of dengue fever (21) and is of particular concern given the potential for increased incidence and spread in the Pacific and globally with climate change (2,22). Samoa is malaria-free; however, malaria is present elsewhere in the Pacific and the potential for malaria incidence and range to increase with climate change is of concern (1). Current initiatives for vector control include health awareness programmes, distribution of mosquito nets, spraying of hot spots and village sanitation inspections. However, a number of constraints have been identified including lack of baseline vector distribution information, difficulties in locating cases and inconsistencies in notification, as well as low community support and implementation in some instances (19). Improving current initiatives will be a key aspect of strengthening adaptation and additional measures may be increasingly needed.

Water and food-borne diseases

Samoa already suffers from a high burden of climate-sensitive water and food-borne diseases. Levels of gastroenteritis in children are high and typhoid has been a persistent problem since it re-emerged in the early 1990s (19). A diverse range of factors is likely to be contributing to this burden including poor access to clean water supplies in many rural areas, poor sanitation, overcrowded houses, and substandard living conditions in some areas (19). Extremely high as well as low levels of rainfall have been linked to diarrhoeal diseases in the Pacific (23).

Floodwaters frequently contain human as well as animal waste. In rural areas, drinking water comes from a number of sources including rivers, streams, wells, springs and roof-supplied tanks; all of which are at risk from microbial contamination. Drinking water is generally untreated (12). Food poisoning and food safety practices have been identified as issues. Higher ambient temperature have been associated with increases in enteric diseases elsewhere, particularly salmonellosis (24). Warmer sea temperatures have been linked with Ciguatera fish poisoning outbreaks in the Pacific during ENSO events (25). Cholera is not endemic in Samoa, but there is some evidence that rising sea temperatures may increase the risk of cholera spreading (26).

Many initiatives at the community and national are already underway including village sanitation inspections; media awareness; case investigation and contact tracing; development of national food safety and water standards; a large national sanitation project funded by the European Union and work on rural community water supplies (19).

Mental health

Issues regarding mental health in children have been previously noted with extreme events such as cyclones. Of particular note, was the extent and nature of mental stress in children as well as adults in the wake of the Tsunami (see case study).

Health sector infrastructure and emergencies

Safe guarding health facilities and emergency preparedness will be an essential part of improving the resilience of the health sector. The recent World Health Organization (WHO) "Save lives: Make hospitals safe in emergencies" report commented that when disasters occur, most lives are lost or saved in the immediate period after the event (27). The impact of disasters is magnified if health services fail or are disrupted.

Health and other critical infrastructure such as water and electricity are at particular risk in Samoa during adverse events such as storms, and cyclones. Communications are also vulnerable with mobile phone network crashes and radio communications in affected rural areas sometimes limited. Work is underway to identify less hazardous new sites for some currently vulnerable rural health services.

Early warning systems and emergency response

The Climate Early Warning System Project is anticipated to significantly assist Samoa in undertaking sectoral and rural communities initiatives to prepare for and minimise the adverse impacts of climate events. Forecasts and warnings regarding rainfall, heavy rainfall events, flooding, drought, cyclones and storm surges are being progressively improved. Early warning relays to remote villages have been identified as an area that needs improving. Along with this, emergency response systems at all levels including government, community, agencies such as the Red Cross, as well as with other countries are being strengthened.

Sustainable tourism

Tourism is a significant employer in many rural communities and supports many families. Visitor numbers could be under threat as a result of climate stresses such as damage to coral reefs and beaches, disease outbreaks such as dengue fever and typhoid fever, water shortages, and extreme events such as cyclones.

Initiatives are planned to improve the resilience and sustainability of the tourism industry though measures such as coastal protection, low-impact developments, climate-proofing against extreme events; and discussion about how could Samoa become a “carbon-neutral” destination as a way to counter these concerns (6,20).

Strategic planning as an adaptation measure

Unplanned growth, both in urban and rural areas have highlighted vulnerabilities that could be exacerbated with climate change. Rural villages have been expanding, particularly along coastal roads close to Apia. With about 70% of Samoa’s population living on the coast, these populations are vulnerable to storm surges, cyclones, sea-level rise as well as tsunamis. Other issues include stress on water supplies, septic tank effluent entering groundwater and coastal ecosystems and building on flood-prone land.

Projects are underway that aim for increased resilience of built and natural environments to expected climatic events. These include sustainable development practices; and integration of climate factors at all levels of policy, planning and consent processes (6). Actions as part of coastal management plans for highly vulnerable rural districts include seawall construction; infrastructure protection; and identification of certain human activities that potentially increase the risk to coastal areas from climate change, such as land reclamation, sand-mining for use in construction, and disturbance of natural currents and deposition processes. There is the potential for relocation of roads and even communities inland to higher ground.

MITIGATION OF CLIMATE CHANGE IN SAMOA AND POTENTIAL HEALTH CO-BENEFITS

Although Samoa’s emissions contribute little to the overall worldwide burden of greenhouse gases, Samoa is very active in mitigation efforts to reduce its emissions (12,20).

Reduction in emissions from the land transport sector has been identified as a priority. Vehicle tune-ups and more efficient vehicles are being encouraged as are public transport, car-pooling and walk to work campaigns. There are plans to construct safe paths and tracks for pedestrians and cyclists. These initiatives could have positive effects on child health through greater physical activity and reduced air pollution; however, there is always the concern regarding injuries to children. Biofuels are being actively explored for vehicles and for electricity generation, in particular, using coconut oil as biodiesel given the surplus of coconuts in Samoa.

Samoa generates a significant portion of electricity from hydroelectricity. Other renewable electricity sources such as solar have been explored, but the expense has limited application to a few remote areas. Energy efficiency is being encouraged through measures such as building standards, awareness campaigns, energy efficient lighting and energy audits. Improving electricity security (shortages have occurred during droughts) as well as potential increases in family income due to energy efficiency may have gains for health.

CONCLUSIONS

Impacts on child health from climate-related events are diverse and may be unexpected. We hope that the Fonofale Model of Health, our adaptation of the Model to portray possible links between climate events and child health as well as the Tsunami case study has been helpful in conceptualising the broad, holistic view of Pacific child health.

While climate change is likely to bring new challenges, noticeably sea-level rise and maybe tsunamis, many of the health problems facing Samoa's children such as diarrhoeal illnesses, water insecurity and dengue fever are preexisting. However, they do have the potential to be exacerbated in a changing world. Therefore strengthening current initiatives as well as introduction of new initiatives will be essential if there is to be an impact on climate-sensitive health conditions and the determinants of these.

Limited information has made it somewhat difficult to comment on aspects that affect rural children in particular, although that they are likely to be more susceptible to water insecurity, cyclones and other extreme coastal events, and families are more dependent on agriculture as a source of income. Baseline data on health conditions (child and adult) has been identified as an area that needs strengthening as part of adaptation measures.

Samoa is active internationally and is part of the Alliance of Small Island States (AOSIS), an effective force in international climate change negotiations. Advocacy of this kind constitutes a vital part of building resilience to protect health.

In the lead up to 2009 Copenhagen climate change meeting, the AOSIS Declaration on Climate Change (28) was announced, which succinctly summarised the current science, concerns and political climate. The Declaration stated that AOSIS was "Gravely concerned" that climate change threatens the viability and very existence of many states and called for rapid, large reductions in emissions by developed countries to limit temperature rises to well below 1.5 deg. C above pre-industrial levels, and long-term stabilisation of greenhouse gas concentrations at well below 350 ppm CO2-equivalent. However, it looks increasingly likely that the world may be committed to at least a 2 deg. C rise in average temperature by 2100 and possibly more, depending on the size and rapidity of emission reductions (or rises) and given some uncertainty regarding rates of ice melt, positive feedback mechanisms and other tipping points.

Adaptation to climate stresses will therefore be essential and needs to occur in all sectors in order to improve and protect the health of Samoa's children. Many issues have been identified with planning and implementation of some adaptation initiatives already underway.

AOSIS was also "Profoundly disappointed" by the lack of ambition in international climate change negotiations to protect vulnerable countries, peoples and ecosystems. Support for adaptation from developed nations must be increased.

Time will tell whether the outcome of international climate change meetings will be continuing profound disappointment and grave concern over what this might mean for the health of children in Samoa and other islands states, and indeed all children.

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Chapter 17

SOCIAL-ECOLOGICAL RESILIENCE AND INUIT CHILD HEALTH

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This chapter looks at remote Inuit communities as coupled social-ecological systems, and places emphasis on how a social-ecological systems approach to studying children's health can shed light on the state of that relationship to date, and on interventions to support the human platform on which future adaptive strategies in remote communities will need to build. In this paper, the resilience of social-ecological systems is discussed in relation to their implications for Inuit child health. The ability to identify, react and evaluate the reaction to surprises while also maintaining essential services is a constant challenge. The SES approach creates a framework for discussing child health in the larger context of social-ecological change. By drawing attention to the challenges that face Inuit children both socially and ecologically it is hoped that additional attention will be paid to the key aspects of SES resilience that will enhance their individual and collective health and wellbeing as well as their adaptive capacity in the face of climate change.

INTRODUCTION

Children are the foundation for future human adaptations to a rapidly changing world. A focus on children's health in isolated Inuit communities in Canada's North underscores the mission of public health to assure the conditions in which people can be healthy and to advance practices that improve the health of vulnerable populations. This paper looks at remote Inuit communities as coupled social-ecological systems (SESs, or human and natural systems) (1) and places emphasis on how a social-ecological systems approach to studying children's health can shed light on the state of that relationship to date, and on interventions

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to support the human platform on which future adaptive strategies in remote communities will need to build.

Who are the children?

While the United Nations' Convention on the Rights of the Child defines childhood as the period from birth through eighteen years of age, this paper focuses on children up to 15 years old. Canadian Inuit populations are very young. In Nunavik, for example, 35% of the population is under 15, and 56% are less than 24 years old (2). One-quarter of new births are to women less than twenty years old (3).

THE CONTEXT: REMOTE COMMUNITIES AND RAPID SOCIAL-ECOLOGICAL CHANGE

While no theory or narrative can ever completely explain observed realities, complex systems theories – in particular notions of resilience – can provide a way to understand SESs, and to visualize pathways to improved health in Inuit communities under conditions of rapid change. Figure 1 summarizes the broad shifts in Inuit community dynamics linked to social and ecological changes over time and space using a resilience model (4). These changes have been occurring over different periods of time (from migrations into North America after the last Ice Age to post-colonial community changes), and at different spatial scales (from the global climate, to local community hunting practices to household eating habits). Framing northern history in resilience terms emphasizes not just the destructive impacts of dramatic changes, but also the adaptive capacity that has enabled the long-term survival of Inuit communities through re-organization and renewal under conditions of severe stress. The question then arises: how and from whom, or from where, have the Inuit social-ecological systems "learned"? Who is learning, and how is that learning incorporated into daily life in such a way as to ensure ongoing resilience?

In figure 1, four main cycles of community resilience are highlighted in the context of social-ecological adaptation among the Inuit over millennia. In particular, the magnitude of the changes experienced by Inuit communities over the past 100 years heavily influences their current resilience and adaptive capacity and sets the stage for a discussion of the forces affecting Inuit children today. The inflexion at the bottom right ("front loop") of the middle level cycle is where Inuit communities have adapted, reorganized and renewed; the different ways in which they have done this (A,B,C,D) are mapped on to the larger, slower scale social and climate cycles in which the community cycles are nested, Changing ecological conditions after the Ice Age, led to widespread migration (A) of human communities world-wide (5). In this way, ancestors of the pre-Dorset people are thought to have arrived in the North five to ten thousand years ago, likely from Siberia, across the Bering Strait (6). A later migration of Thule people from Alaska into Canada are said to be the true ancestors of contemporary Inuit (7). During this period several significant climate changes occurred, including periods of colder and warmer than present conditions (7).

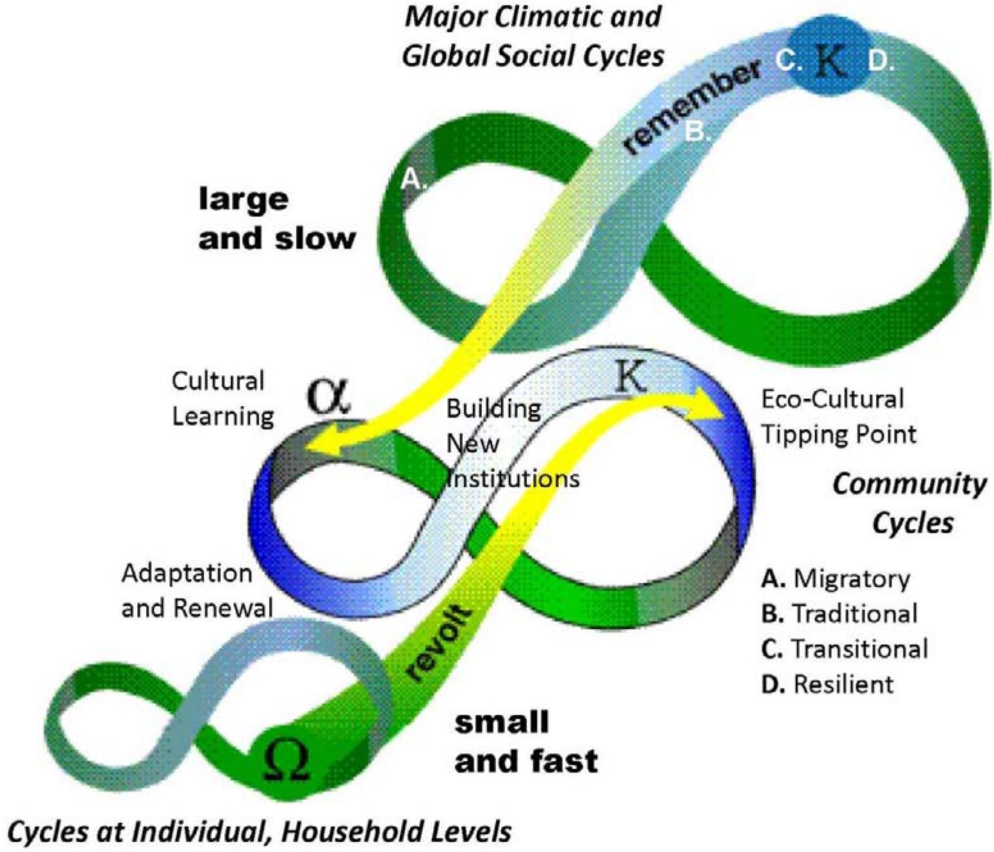

Figure 1. Cycles of social-ecological resilience at different spatio-temporal scales. Adapted from Gunderson LH, Holling CS. Panarchy: understanding transformations in human and natural systems. Washington, DC: Island Press, 2002 (4).

During the second phase (B), lasting approximately five hundred years, traditional Inuit societies in remote areas adapted to ecological conditions in their regions. While the overall climatic conditions were relatively stable, large variations in seasonal and annual weather and wildlife populations heavily shaped Inuit culture and worldview, and cultural adaptation was based on seasonal movements between settlements and activities (8). Over hundreds of years, many iterations of this traditional cycle of community social-ecological development were possible.

Canadian Inuit contact with European society began as early as five hundred years ago on the East Coast of Canada, and regular trading relationships were established by the late 1700's. After World War II, however, significant changes in Inuit community social and cultural dynamics, initiated during the colonial era, accelerated, and were linked to the more active engagement of the Canadian government in Inuit affairs. This transitional period (C), began with the period of immigration and settlement from the 1940s to late 1960s and included resettlement to previously uninhabited parts of the High Arctic (e.g. Grise Fiord and Resolute Bay) and the transfer of children to residential schools. The change from a migratory existence to settlement in permanent communities with Western religion (particularly

Christianity), schools, stores, jobs and television has significantly altered traditional lifestyles (9,10). Such interventions unleashed a wave of rapid social change in Inuit communities.

During this time, the health of Canadian Inuit underwent an 'epidemiological transition' from acute to chronic illness such as obesity, diabetes and cardiovascular illness. Inuit children suffer from significantly higher rates of morbidity and mortality than other Canadian children. Key health statistics point to high incidences of suicide, middle ear infections (linked to inadequate housing, poor nutrition and a smoke-filled environment), tuberculosis, teen pregnancy, and although only limited data are available: family violence, substance abuse and fetal alcohol spectrum disorder are also of significant concern (2, 11).

In the current resilient cycle (D), the impact of climate change is already being felt (12) and these changes are layered on top of the already-significant "epidemiologic transition". Major ecological changes in the north are associated with direct and indirect health effects including the mental and social stresses of a changing community and culture. The so-called 'Arctic Dilemma' poses a significant challenge for advocates of child health and development. On the one hand, traditional 'custom' foods, particularly high-fat foods from marine sources, have a number of significant health-promoting effects (including essential fatty acids, high quality protein and micronutrients as well as well-being benefits tied to Inuit community and culture) (8). On the other hand, these foods often contain anthropogenic contaminants, such as heavy metals (particularly mercury) and organochlorines that are of particular concern for fetal and child development. Even low doses of POPs and other endocrine disruptors can interfere with developing organisms' reproductive, immune and neurological function (5). Chapin et al. report that "In coastal Canadian and Greenland communities where marine mammals are a significant food source, concentrations of POPs in mothers' milk are high enough to be considered a health risk, and the consumption of wild foods has been restricted in several cases in the eastern Canadian Arctic" (8 p. 737). According to Hansen, the most vulnerable age groups are fetuses, children and young people of reproductive age and that once past their reproductive years, "food preferences should be left to the individual to decide, as an informed choice" (13 p. 367). Discrepancies between actual and perceived risk related to the consumption of country foods continues to challenge both the health and well-being Inuit communities.

It is in this broad context of rapid social-ecological change that Inuit child health must be situated.

A SOCIAL-ECOLOGICAL SYSTEMS APPROACH

In this paper, Walker et al's 'defining characteristics' of resilience in social-ecological systems, are discussed in relation to their implications for Inuit child health (14). In this context, a resilient system is one that is constantly evolving and self-organizing to deal with existing and emerging situations and issues. There is no one "steady-state". A resilient system does not 'reset' to a previous condition, but maintains key functions in a changing context. The ability to identify, react and evaluate the reaction to surprises while also maintaining essential services is a constant challenge. The three characteristics are: the amount of change the system can undergo and still retain the same controls on function and structure, the degree to which the system is capable of self-organization and the ability to build and increase the capacity of the social-ecological system for learning and adaptation (14). A social-ecological systems (SES) emphasis on future generations provides a strong entry point for the discussion of child health and climate change adaptation. A key question is what can SES approaches offer that is different than the current and significant concerns being raised about child and maternal health in Inuit communities.

In the paragraphs that follow, Walker et al's three characteristics (14) are discussed as they pertain to Inuit child health.

The amount of change the system can undergo and still retain the same controls on function and structure

Q: What are the key elements of Inuit communities that can support resilient Inuk populations as they navigate a rapidly changing world?

Inuit culture has adapted, reorganized and renewed itself for thousands of years under almost insurmountable odds. In the current resilient cycle dominated by climate change narratives that highlight threats of system collapse and great risk, Bravo takes a critical look at the portrayal of Inuit communities as both victimized and 'at-risk communities', lacking the agency to fight back against the forces that are threatening them, and as keepers of valuable traditional knowledge (15). A fundamental question persists about whether or not their inherent self-organizing ability, which has emerged under conditions of catastrophic ecological and social change in the past, can be mobilized to deal with the effects of rapid, widespread and irreversible climate change such as thawing of permafrost, the loss of sea-ice and vegetation change, as well as the Westernization of Inuit economies and cultures (5). As McElroy states:

> When the lives of people of differing cultures gradually become enmeshed, and as new behaviours are copied and adopted, a new culture begins to emerge. Many small variations occur within each generation's life cycle, from childhood to old age, and over the decades one sees major transformations (7).

How such transformations will play out in the resilience cycle remains to be seen. As part of a broader effort to articulate key elements of Inuit culture (for example to influence governance structures in places such as Nunavut), several key concepts have been identified. Inuit Qaujimajatuqangit (IQ) is an expression for Inuit traditional knowledge; particularly the wisdom of Inuit elders. The concept of Inuuqatigiittiarniq, the healthy interconnection of mind, body and spirit, reflects the Inuit's holistic view of health. Inuit ecological knowledge (IEK) is characterized by Thorpe as including that which Inuit have always known. The author defines nine characteristics of Inuit ecological knowledge: aggregating, changing, orally passed, intergenerational, multifaceted, local, iterative, adaptive and spiritual and compares it to modern scientific knowledge (16).

Inuit cultural practices have evolved in response to their challenging environment. For example, traditional Inuit custom adoption is the practice of giving children to family members to raise, with birth parents often seeing their children daily and maintaining close relationships with them (7,9,11). Custom adoption may occur when a family has many children in close sequence and there are concerns that they cannot all be fed. Alternatively, a family many have children of only one sex and adopt a child of another sex. Although in recent years some have expressed concern that custom adoption has become less an investment in community than a means of dealing with unwanted pregnancies (9,11), it is still evident that the practice is based in the value of Inuit children to the whole community.

Inuit children facing a future of unknown and rapid social and ecological change will be challenged by the ability of Inuit traditions and traditional knowledge to provide guidance on how to adapt to the dynamic social-ecological construct that is emerging. It is in this context that the wisdom envisioned in the IQ framework, and reclaiming of some traditional practices, becomes even more important. The characteristics of IEK are well suited to the resilience paradigm. How to create mechanisms that support this kind of intergenerational learning is a key challenge.

If resilient systems can be considered those that can adapt to change and still retain controls on structure and function then what are the key elements of Inuit communities that can support SES resilience in a rapidly changing world? These key elements are fundamental to supporting the well-being of Inuit children, including their mental, cultural and spiritual health. From the literature, some key features of Inuit community may be identified. These include use of the Inuktitut language (included as an indicator of early childhood development conditions (17)), political empowerment, and the development of the IQ concept in both culture and governance (18). The importance of the subsistence lifestyle and time spent 'on the land' also appear to be fundamental elements of Inuit culture.

THE DEGREE TO WHICH THE SYSTEM IS CAPABLE OF SELF-ORGANIZATION

Q: How can Inuit communities self-organize to create resilient communities?

The degree to which a social-ecological system is capable of self-organization is another challenging question for Inuit child health. IQ emphasizes that learning and self-organization take place through social networks ("capital") in the communities themselves, in response to a variety of information sources. Political empowerment is fundamental, but so is self- and community- empowerment to tackle serious social issues such as suicide, teen pregnancy, smoking and substance abuse. The National Inuit Youth Suicide Prevention Framework report highlights this message in its observation that there is a lower incidence of suicides in Inuit communities that have taken control over and responsibility for its prevention (19).

Arctic food systems have changed. Contaminant levels in marine mammals are high enough that scientists are calling for dietary restrictions for women of childbearing age and young children. This message, however, is nuanced by the need to support traditional Inuit lifestyles and food preferences. The many health-promoting qualities of 'country foods' preclude population-wide restrictions. In this context, the ability of Inuit populations to acknowledge threats to fetal and child development by providing nutritious alternatives for women of childbearing age and young children is fundamental. At the same time, Inuit communities need to band together to address the subtleties of this public health message by not avoiding country foods altogether. This is a particular challenge where the exorbitant cost of store-bought food, often of low nutritional value, has contributed to food insecurity and shortages in Inuit households (2,20). Hansen notes that policies to support changing food preferences from more highly contaminated local food species, to less contaminated local species (including musk-ox, and fish) could encourage year-round food supplies without resorting to an over-dependence on imported food (13).

In their article on building resilience and adaptation to manage Arctic change, Chapin et al suggested that, as northern communities adapt to their novel social-ecological conditions, people “seeking to sustain traditional activities will encounter a disproportionate number of challenges, whereas most of the opportunities are for the development of new activities and infrastructure that are now more typical of southern areas” (8:199). Broadening the established kinship culture that links office workers with subsistence hunters (8) through the sharing of resources, particularly hard currency and country foods, may provide a basis for community adaptation to Inuit life that also enhances food security and Inuit culture. Co-management arrangements that connect the knowledge and experience of people ‘on the land’ with local communities and government managers can create local feedback loops that help remote communities learn and adapt to changing social-ecological conditions (8,21,22). Increasing the time spent on the land allows Inuit people to “observe and develop the knowledge that strengthens their ability to adapt” (5:661).

There are many examples of actions being taken by communities to implement positive and long-lasting changes. Indeed, some actions that build on self-organization to promote healthy communities can be disproportionately empowering to Inuit communities, such as the repatriation of childbirth to remote communities (as opposed to the evacuation of pregnant women to regional hospital settings) through investments in a more culturally sensitive, midwifery-led approach. As a Puvirnituq Elder states “To bring birth back to the communities is to bring back life” (2:384).

The ability to build and increase the capacity of the social-ecological system for learning and adaptation

Q: What kind of local social and ecological information is available to shape community decisions and behaviour? Increasing the capacity of Inuit communities to learn about and adapt to their rapidly changing circumstances is an overarching theme of the resilience framework. In remote Arctic communities, investing in education goes well beyond the construction of schools and depends on concurrent investments in information and communication technologies, alternative schooling, experiential and social learning and support for regional university and vocational institutions. Learning and adaption for resilience also needs to be heavily attuned to ecological change. There is an urgent need to invest in local institutions and programs dedicated to understanding local environmental changes and their impacts on Inuit health and security. Public health data alone are insufficient to provide a realistic evaluation of the cumulative and synergistic effects of rapid social and ecological change. Without locally specific data on both the social and environmental determinants of health, it is difficult to envision locally relevant feedback systems that will support on-going learning and adaptation.

Programs like the community-based monitoring for climate and health (23), the Arctic Borderlands Ecological Knowledge Co-op (24) and the Arctic Water Resource Vulnerability Index (25) may provide much-needed local support for social-ecological adaptation.

DISCUSSION

In the Inuit context, a key challenge of the resilience framework is to critically examine how traditional Inuit culture can be a vehicle for integrating new information related to climate and social change to promote child health. Discussions pertaining to the elements of Inuit culture that are non-negotiable (e.g. language) may also highlight areas that are open to change (e.g. dietary habits of women of child-bearing age and children). As Hansen notes "the time has come for a new paradigm … defining traditional food in a renewed form and, at the same time, reducing the exposure to contaminants" (8:368). Operationalizing this observation may lead to some new ways of thinking about Inuit livelihoods and community food security. Ultimately, conversations about social-ecological resilience in the context of child health touches on very sensitive issues around what it means to be an Inuk in the 21st Century. These determinations can only be made by the Inuit themselves.

A clear focus on children's health may help Inuit communities elaborate a path through the turbulent times ahead that protects the most vulnerable members of their communities and enables them to continue their process of reorganization and renewal. Methodologies such as the Diamond Diagram and the Adaptive Methodology for Ecosystem Sustainability and Health (26) may be useful in creating a structured approach to study such complex, transdisciplinary and intersectoral issues.

Future-based planning and uncertainty

The social-ecological systems literature is characterized by its focus on both the current and future states of ecosystems and on human visions and aspirations. Several SES methodologies make specific references to future-based planning methods, such as visioning and scenario-building. Scenario-based understandings of Inuit child health and development are one mechanism by which the cumulative and synergistic effects of rapid social and ecological change may be better understood by affected communities. Thinking through the implications of such scenarios could lead to a suite of interventions that emphasize not only intergenerational equity and health, food security, maternal health and women's issues, but also climate change adaptation measures. Inputs into such scenarios would include the social and environmental determinants of health that we currently see in Inuit children in remote communities. The synthesis of information could as well be through narratives, metaphors and stories as through models or diagrams. Context is fundamental – these determinants manifest themselves very different in differently in individual communities.

CONCLUSION

It is not enough to think out about the conditions Inuit children are growing out of: equally important is to consider the social-ecological system they are growing into. The SES approach creates a framework for discussing child health in the larger context of social-ecological change. By drawing attention to the challenges that face Inuit children both socially and ecologically it is hoped that additional attention will be paid to the key aspects of

SES resilience that will enhance their individual and collective health and wellbeing as well as their adaptive capacity in the face of climate change.

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Chapter 18

THE GLOBAL FINANCIAL CRISIS, CLIMATE CHANGE AND RURAL CHILD HEALTH

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Much evidence exists to suggest that health is strongly influenced by socio-economic factors, but also climate change. This chapter aims to explore the interacting effects of the global financial crisis (GFC) and climate change on the health of children in rural Australia. Strong evidence is emerging that the GFC will continue to have major economic effects in rural Australia. These economic effects will in turn impact on vulnerable groups such as rural children. Indigenous children may be particularly affected, but the GFC may also interact with climate change to create new groups of disadvantage amoung rural children. Prevention programs are at risk as is the viability of many non government organisations working to achieve better health for rural children. Declining rural neighbourhoods may also affect health, as will changing patterns of healthcare utilisation. The conclusions emphasise five key directions for the rural health sector: 1) helping ensure that there is support for local community responses including through local councils; 2) ensuring that the three pillars of the government's policy response to the GFC (infrastructure, education and business development) do not create silos that exclude health, a task requiring the rural health sector to be visible at economic reform discussions and in economic policy development; 3) insisting on reform of Australia's scant health service research agenda; 4) however uncomfortable, questioning the values that have led to unhealthy outcomes for rural communities and 5) developing an explicit rural health policy with sentinel indicators agreed on at state and federal levels.

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INTRODUCTION

As the United Kingdom's watershed report the Independent Inquiry into Inequalities in Health concluded, the last century has seen dramatic falls in mortality in developed countries, although socio economic differences in life expectancy and health status have persisted (1). Over the last twenty years in particular, a vast body of evidence has accumulated to suggest that health is strongly influenced by socio-economic factors: that health is distributed in ways that are closely linked to the social and economic conditions of people's lives (2,3). The World Health Organisation's Commission on the Social Determinants of Health concluded in 2008 that making a difference to health is about improving living conditions and bringing greater equity to the distribution of wealth—that the social determinants of health are responsible for the major part of health inequities between and within countries (2). The English Longitudinal Study of Ageing found that wealth, not simply income, powerfully predicted health status (2,4,5). Other studies of unemployment suggest a strong link between unemployment and mortality: unemployed people may have as much as 25% higher rates of mortality than comparable others of their socio economic group (4-7). There is considerable evidence that being unemployed or under-employed is linked to longer-term mental health problems (8). It is also known that the suicide rate in young males correlates to their levels of unemployment (8) The experience of the 1990s Asian monetary crisis also brought an awareness of how economic downturns can impact on health, including by way of sharp increases in mental health conditions and suicide (5,9), as well as cardiovascular mortality and complications (10).

Australian research has long shown that socio economic status has an important role in unequal health outcomes (11). including in rural and remote regions which have less equitable distributions of income and higher proportions of people in receipt of government pensions and benefits (12). Socio economic status and Indigenous status are two of the greatest underlying factors in shaping the health of people in rural and remote communities (11). In fact, when socio economic status is taken into account, rurality may be no longer statistically associated with some health conditions such as Acute Myocardial Infarction (13).

The social determinants of health are, of course, far broader than such 'front-line' economic shapers of health as 'income' and 'unemployment'. For example, psycho-social factors play important roles in explaining the unequal health outcomes in rural and remote Australia. Factors such as poor health literacy, as well as rural attitudes to healthcare shaped by entrenched self-reliance and stoicism, are linked to lower health utilisation in rural communities (11).

The emerging evidence suggests the importance of considering the total context of rural child health. Other papers in this volume have also pointed to interactions between climate change and economic factors in understanding outcomes for rural child health. This chapter aims to explore the particular directions for policy advocacy by the rural health sector that are indicated by evidence of these interactions. It identifies five key directions that the rural health sector could take for achieving better rural child health outcomes in the wake of the GFC, through its health policy advocacy work.

KEY WORKING DEFINITIONS

The global financial crisis or 'GFC' has been described as 'a liquidity crisis'. It was ostensibly brought about by rising interest rates in July 2007 and a constricting US economy which led to rising home mortgage defaults. This revealed a wide range of questionable credit practices as investor confidence sank and major investment banks began to collapse. This in turn led to a lack of liquidity in the banking system in the USA and in other countries. Government responses provided billions to prop up ailing bank, credit and consumer markets. The Australian government acted quickly to guarantee bank deposits up to one million dollars as well as take other steps to secure investment and consumer confidence. However, while it appears that Australia has escaped the worst effects of the credit collapse due to this early action, the Australian stock exchange fell as exposed businesses collapsed, consumer confidence declined, and job losses were felt (14).

These recent events occurred in the context of climate change in Australia. According to the Fourth Assessment Report of the United Nations Intergovernmental Panel on Climate Change, climate change is defined as 'any change in climate over time, whether due to natural variability or as a result of human activity' (15:2). This definition contrasts with the United Nations Framework Convention on Climate Change, where climate change refers to 'a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods' (15:2). While the question of whether climate change is anthropogenic or not has importance for decisions about mitigation or adaptation, in this paper the primary focus is on understanding the impacts of changing climates on rural and remote communities.

'Health policy advocacy' in this paper is defined as an attempt to shape health policy through adversarial, evidence-based means such as research, facts, and related arguments. Drawing on the author's previous work, this paper defines 'health policy' as 'a set of actions taken by an administration to control the system, to help solve problems within it or caused by it, or to obtain benefits from it '(16,17). Policy can operate at the micro (local community), meso (regional) or macro (national/international) levels (17). The conclusions in this paper address all these three levels of policy-making.

The Australian 'rural health sector' in this paper is defined as a loose confederation of patients, practitioners, health service administrators, researchers and advocates in professional organisations and consumer interest groups who have an interest in improvements to the health of rural Australia. The peak organisation for the sector is the National Rural Health Alliance (NRHA), comprised of 29 national organisations representing rural and remote health consumers, service providers and professions. Those discrete bodies undertake their health policy advocacy both individually and within the NRHA. They include the Rural Doctors' Association of Australia, National Aboriginal Community Controlled Health Organisation (NACCHO), the Australian Rural Health Education Network (ARHEN), the Rural Faculty of RACGP, the Australian College of Rural and Remote Medicine (ACRRM), the Council of Remote Areas Nurses of Australia (CRANA), and Services for Rural and Remote Allied Health (SARRAH). There are also many other organisations at local, state, and national level which have a role in representing rural health interests. All of these organisations have an interest in shaping federal government public health policy. This paper is designed to support the policy advocacy work of these agencies.

‘Rural child health’ is a term that encompasses young people from the neonatal stage to mid adolescence (16 years). It refers to all such individuals living in non urban areas variously included in the terms ‘regional’ and ‘remote’ i.e. in the Australian Standard Geographical Classification (18).

This paper also covers a wide range of different kinds of services involved. That is, it covers health service delivery (understood in terms of primary health care and acute care services), ancillary care (such as social support agencies).

METHOD

Much of the evidence about the effects of the GFC in Australia on rural children must be extrapolated from a wide range of diverse sources. There is currently no published paper on the subject. Accordingly, the author has used a ‘snowballing’ technique: beginning with key published texts by policy active organisations and working out from reference lists so identified. Thus the method involves not only PubMed searches from 2007 to the present using variations of the terms ‘global financial crisis’, but also checks of the websites of key agencies in policy advocacy such as the WHO, UN, and Research Australia, and checks of reference lists of sources so identified.

In relation to climate change, while there are over 850 papers on its health effects, these are largely recent papers and examination of issues for rural child health is still in its infancy. The difficulties this creates for drawing conclusions are suggested by other papers in this volume. In keeping with the aim of this collection—to offer a starting point for a new field of enquiry into rural child health in a context where definitive empirical studies are few and far between—this paper takes the form of a policy discussion paper. While it is certain that climate change is happening, there remain major gaps in knowledge about specific effects for particular regions. These gaps are particularly notable for rural and remote communities. Such gaps are suggested by the small number of Australian studies of climate change as it relates to rural health, as well as key documents such as Australia’s National Climate Change Adaptation Plan for Human Health (NARP)(19).

Accordingly, the author has chosen to first construct a framework understanding of the effects of the GFC on rural child health, and then to use this to extrapolate outwards to insights about interactions with climate change. A key challenge of this approach lies in the temporal relationship of the GFC to climate change. That is, climate change will involve accelerating changes and subsequent influences on human health. In contrast, the GFC and subsequent economic shocks will have their major effects at a particular point in time. Thus the effects of the GFC need to be understood as interacting with the escalating effects of climate change.

This approach is seen to be most useful for a paper that aims to identify directions for health policy advocacy work—broad directions for policy advocacy where it is reasonable for the rural sector to act. It is acknowledged that such an approach would not be suitable for trying to arrive at fine-grained empirical judgements and is unlikely to satisfy rigorous standards of epidemiology. However, in policy contexts evidence is often scant and only just emerging. A broad direction from research that straddles a wide range of evidence and opinion can be useful if it is both novel (addresses a neglected area) and reasonable (in the sense that waiting some years for empirical studies would bring unreasonable hardship to particular vulnerable groups). In the case of the GFC and climate change, waiting for conclusive evidence of health effects may not leave sufficient time to respond appropriately. That is, policy development for such events cannot wait for evidence of past trends or present health crises but rather must be pre-emptive and futures oriented.

FINDINGS

Key economic effects on rural and regional australia

While Australia is considered to have escaped the worst effects of the GFC, it is certain that a wide range of effects, including on government, consumer and philanthropic spending now and in the future, will continue to be felt (20). Piecing the evidence together for the specific health effects of the GFC on rural and remote Australia is about engaging with the fact that crude 'area-based' assumptions do not work so well to explain health inequities between these regions and urban Australia (21). The comparative epidemiological evidence does not support the view that 'geography is health destiny'—rurality as such does not always confer poorer health status. The effects of the GFC on health will depend on how socio-economic patterns of disadvantage—which are part of the structural and social roots of poorer health outcomes in 'the bush'(21)—interact with climate change to affect rural and regional Australia.

To begin, is it correct to say that the GFC has and will continue to affect rural and remote Australia worse than urban Australia? Scholarly and applied information on the effects of the GFC on rural and regional Australia is only just emerging. The November 2009 report of an enquiry by the House of Representatives Standing Committee on Infrastructure, Transport, Regional Development and Local Government into the impact of the global financial crisis on regional Australia outlines a wide range of effects. These arise primarily from the loss of major export businesses and impacts on small and medium-sized regional businesses. Increasing unemployment and reduction of working hours has been reported, along with mortgage stress and rising mortgage default. The shedding of work hours has produced the greatest social impacts through loss of income in regional Australia (14). In Australia, while unemployment has not risen as steeply as predicted, there are over 1.5 million Australians who are either unemployed and looking for work (616,000) and 900,000 who are seeking to work morer hours of work than are available to them at present (ABS statistics for February 2010, 13% labour force underutilisation) (8).

Regions that are heavily reliant on mining and tourism in particular are feeling the effects of the GFC. For example, in the mining sector employment has fallen by 5.2% since February. In particular areas such as Broken Hill there has been a 30% decrease in employment. Regional towns and indigenous populations in the Northern Territory have been hard hit by the decline in international tourism, with a reported decline of 12.4% in visitor numbers in the 2007/2008 period. However, it appears that some of the worst declines in tourism have been felt in far north Queensland with August 2009 figures showing the highest rates of unemployment (10%) in the country. These regions are experiencing a wide range of 'knock on' effects, as workers are forced to relocate and small businesses decline in the area (14).

Manufacturing activity in regional Australia has also been hard hit by the GFC, in areas such as Geelong and Wodonga. Yet effects have also been felt in much smaller country towns where a single manufacturing business is a major employer. Again, the decline of a single manufacturer has a multiplier effect as a whole host of smaller supply businesses are impacted, including retail outlets. Commercial and residential construction has also been in decline in regional Australia: for example, in the greater Bunbury area residential construction has declined by 70% with 1,500 construction jobs lost. Farmers and small businesses have suffered from credit access problems, impacting on rural and regional development capacity. Forestry jobs in, for example, Tasmania, have been lost, as export markets have declined in countries hard-hit by the GFC. Discretionary products in the fisheries industry have also been affected in rural and regional areas, with consequent loss of income to, for example, lobster fishermen in Western Australia (14).

However, the news is not all bad. Although commodity prices have dropped leading to job losses in regional Australia (14) and the market for many Australian agricultural products continues to be volatile, demand for food can remain strong in times of economic downturn. The World Bank has predicted that food prices will remain at least around 25% higher than they were in the 1990s (22). Farmers in developing countries could benefit from high food prices (23). This may, however, be offset by rising nationalism and protectionism across the globe.

The true cost of the global financial crisis

The full cost of the GFC is unknown and much of the evidence is anecdotal and not based on large scale empirical studies. It is certain however that climate change—increasingly well-documented in the research on rural and remote health (24)—is also continuing to interact with the GFC to multiply economic hardships for rural and remote communities. The prolonged drought and its effects such as poor crop yields has impacted heavily on the well-being and resilience of rural communities in the face of the GFC. Where drought conditions have improved, the GFC has had less of an impact (14).

The mixed picture of how rural Australia is faring is about understanding complex interactions between two great present drivers of the human condition—the GFC and climate change. Understanding these interactions requires a combination of diverse regional and national comparative information: articulation of micro, meso and macro policy-relevant data of different kinds. Tasmania offers one kind of example of these complex interactions. The April 2009 Australian farm survey results produced by Australian Bureau of Agricultural and Resource Economics suggests that the expected improvements in farm financial performance will not be realised in many southern region areas affected by drought and irrigation water shortages, with Tasmania showing the worst average loss of farm business profit (25). On the other hand, the GFC has brought some good news for domestic tourism: Tasmania (with a 12% increase in visitors) has also been positively affected due to the growing domestic tourism market as international tourism falls away in the wake of the GFC (14). A closer look at precisely what regions of Tasmania are most affected by drying (midlands to central highlands) raises questions about whether the tourist dollar will really benefit those areas, as they hold fewer tourist destinations.

Much attention has been given to the economic effects of the GFC, however, the health effects may be more difficult to overcome in the long-term, including as they interact with climate change.(8) What do we know about these health effects in rural Australia, especially as they relate to a most vulnerable group—children?

Vulnerable groups

The effects of the GFC in rural Australia are likely to be critically felt by particular vulnerable groups. To date much emphasis has been on the effects of the GFC on older Australians. Most rural and remote communities have higher proportions of Australians over 65 years (26), a group already hard hit by the GFC. Community Services Minister Jenny Macklin reported a 50% increase in the number of people granted the aged pension between October and December 2008 as the GFC bites into superannuation and other retirement funds (27). A $14.2 billion Secure and Sustainable Pensions reform package was included as part of the 2009 10 Commonwealth Budget; the GFC being cited as underscoring the need to provide a sufficient safety-net for older Australians. The GFC is thus likely to erode the capacity of older Australians to provide for themselves, contributing to long-term rises in aged care costs (projected to rise from $84 billion in 2003 to $246 billion in 2033) (8). These will create issues of intergenerational equity as these older groups place greater imposts on government spending.

Rural child health has received very little attention in analyses of the social impacts of the GFC. However, there have been reports of increases in youth allowance claims as well as reports of steep increases in mortgage stressed families (14). Entrenched disadvantage in families experiencing long-term unemployment or under-employment is likely to be reflected in the present and future health and well-being of children. Poverty and poor housing will help create the conditions of social exclusion that perpetuate intergenerational poor health.

Children in already disadvantaged families with lower education levels and pre-existing health conditions are extremely vulnerable to the negative effects of the GFC and climate change. Long-term disadvantage in these families and their children is likely in turn to lead to shorter life expectancy, increased chronic disease, injury and poorer mental health (8). Reports are emerging from Europe that the GFC may be linked to rising incidences of substance abuse: Australia may expect similar effects (28). The children of unemployed single parent families are known to be particularly vulnerable: in rural regions experiencing negative effects of climate change these are likely to be one of the most disadvantaged groups. Children from the neonatal stage to adolescence will be affected. The children of pregnant women in low income households also exhibit early age impacts such as mental health and behavioural problems (8). Parental employment is positively linked to mental well-being in adolescents (8).

It is known that, due to increases in the indigenous Australian population over time, inequities in health outcomes between rural regions and urban Australia increasingly reflect the higher morbidity of indigenous (as well as older) people (26). This has important implications for rural child health. Unless the government is able to sustain and strengthen its focus on indigenous health programs, the GFC will hamper Australia's efforts to close the gap between the health outcomes of its indigenous and non indigenous populations, including in critical areas such as neonatal deaths where the burden of disease is much higher in indigenous populations (21). The increasing pressure, on for example food supply, brought about on these particular communities by climate change (29) may also work to offset any gains made by government policy.

Many less obvious effects of the GFC on the health and well-being of rural child health may occur. For example, the quality and extent of casual youth employment may be adversely affected. This may negatively affect the ability of young people to take positive pathways from home to work and further study.

The weakened capacity of rural families or weakened confidence in their medium-term capacity to support children in finishing secondary education and in undertaking higher education would be a particularly adverse effect. Year 12 completion rates for students in regional and remote areas are 62% and 52% respectively, less than the 69% rate for urban Australia, while students from regional rural and remote areas are less likely to attend higher education across all socio-economic groupings than their urban counterparts (30). 2005 figures show that only 17 % of university students are regional/rural (31).

Financial capacity is a significant barrier to education access and can result in intergenerational restrictions on prosperity, career choices, health and well-being, and also on the supply of professionals, such as teachers, doctors, dentists, engineers, veterinarians, accountants and others willing to work in rural Australia.

Prevention programs

Australia's recent 2020 report on health prevention suggested that alcohol, tobacco and obesity prevention programs are critical to addressing health inequities in rural and remote Australia (32). It is known that the main contributors to the higher mortality rates in rural Australia are preventable conditions such as coronary heart disease, traffic accidents, and chronic obstructive pulmonary disease, linked to lifestyle factors and behaviours (33). Indigenous people have much higher mortality rates than non indigenous Australians: among indigenous Australians the leading causes of death such as diseases of the circulatory systems, injury and cancers include many preventable conditions. Health education to prevent some of these conditions must begin early if rural children are to have positive and healthy futures (34).

The GFC, together with the rising health burden of climate change, bring the risk that, as a recent WHO consultation document on the GFC suggests, governments will focus on acute care and be unable to sustain support for prevention programs (35). Disadvantaged groups tend to use acute and primary healthcare services to a greater extent than preventative health services (8). Yet the needs for prevention programs will be considerable in the wake of the GFC and climate change, as economic conditions erode the health and well-being of Australians and shift the focus onto economic survival (28). Prevention programs such as tobacco control programs need to engage with the broader social determinants of tobacco use, known to powerfully shape the relatively high tobacco use in indigenous communities, including among youth (34,36).

The continuing high cost of food, linked also to climate change, has been flagged by the WHO European Region as a key area in which the GFC may impact on health. Deteriorating employment conditions will force many households to cut back on spending on fresh food, with consequent negative effects on health, especially for the most vulnerable,(28) such as children. The nutrition-influenced health and well-being of children—including in the long-term—is known to be greatly affected by poverty (5, 37). Specifically, effects may be seen in childhood obesity and diabetes among children in low income rural and remote families.

New groups with unequal health outcomes

The GFC may also create new groups or categories of people with vulnerable and unequal health outcomes in rural and remote Australia, such as causal workers whose health has been affected by ongoing insecurity of employment (5,38). Recent data from the independent social services sector in Australia suggests that already overburdened areas such as residential aged care, housing, homelessness and family relationship services are struggling to meet demand from new kinds of clients such as 'mid-stream' income earners who were already presenting in growing numbers during the so-called economic boom times in which too many Australians did not participate (39). The GFC may have major effects on the job security of previously prosperous 'tree-changing' professionals in rural Australia, in regions affected by casualisation of labour, with consequent effects on their health as they shift to casual and part-time working conditions. These new groups of rural Australian families affected by economic stress means that new groups of rural Australian children with previously positive health futures now face a far more precarious health future as their families also experience the true costs of the GFC in a climate-changing landscape.

Role of non-government organisations (NGOs)

Responses to complex social challenges such as mental health problems and domestic violence in rural communities rely on a complex range of health and social services, as well as other community supports, being adequately funded. Reports are emerging in Australia of overstrained non government organisations (NGOs) which are unable to meet increased pressures as the numbers of families seeking welfare assistance continue to rise (14).

It is certain that donations to many not-for-profit agencies with a role in health, including rural health, are likely to see major declines after at least a decade of increases in philanthropic activity linked to increases in the role of non profit organisations, faith-based groups and non profit interest groups in health (40). Flagship not-for-profit charitable organisations in rural and remote Australia, such as the Royal Flying Doctor Service, rely in part on donations from the corporate sector for critical capital purchases such as essential medical equipment for neo-natal intensive care units. Not only that, but organisations such as the Country Women's Association (CWA) have a strong role in building the social capital and collective efficacy of mothers in rural communities, providing support structures for families. The nation's NGOs have been active in many other ways that ensure the viability of rural Australia in climate-changing times. For example, the CWA has a Landcare program that aims to support farmers to develop innovative sustainable farming practices in climate-affected rural regions. The CWA has worked closely with corporate Australia to develop drought relief programs helping thousands of Australian families.

Thus NGOs have had a most important role to play not only in terms of healthcare delivery in 'the bush' but also in helping build rural community resilience to both the GFC and climate change. These organisations have helped Australia respond to recession and crises such as drought and bushfires,(8) as well as complex health 'knock on' effects such as substance abuse and suicide in rural communities. They also deliver key community well-being initiatives such as arts in rural and remote health,(41) which are important to the health and well-being of rural children. Threats to the funding of such organisations may have indirect effects on health where, for example, a community is less able to rebuild after climate-influenced disasters or lobby for better policies, including health policies (13).

Declining neighbourhoods

The health effects of the GFC in rural and remote communities may also be felt through changes in 'neighbourhood characteristics' driven by the economic downturn. These effects can be complex and wide-ranging. For example, there is some evidence that lower neighbourhood socio economic characteristics (not just crime) influence both 'physical' disability and 'going outside the home' disability in older people (11). However, an emerging body of 'neighbourhood literature' is demonstrating important relationships between neighbourhood characteristics and child well-being across a range of physical, cognitive and behavioural measures (42). The socio economic status of neighbourhood populations may also influence the quality of food outlets and thus the nutrition of families and children within those communities (13). Thus the GFC may also create new pockets of disability, ill-health and disadvantage among rural Australians through such indirect neighbourhood effects. This may work in less obvious ways, for example, to increase the numbers of young carers providing at-home support for their parents or grandparents—one of Australia's most invisible groups (14).

Healthcare

Turning to the acute care sector, in America some rural hospitals have been relatively insulated from the GFC by virtue of the fact that they are not funded by large Fortune 500 companies (43). However, more generally an already economically polarised America is seeing a restructuring of the private healthcare market arising from increasing gaps between the 'haves' and the 'have nots', as particular private healthcare markets collapse in the wake of the GFC (43). Fears of negative effects on healthcare utilisation by vulnerable groups is a key issue in WHO European Region considerations of the GFC, particularly for countries without universal health coverage (28). As noted in the January 2009 WHO consultation (35) on the global financial crisis and health:

> Experience has shown that spending in the private sector tends to decline in an economic downturn, as patients either defer care completely or turn from the private to the public sector,

> if care is available at lower cost. Unless public sector services are ensured adequate financial support in these circumstances, quality of care is likely to deteriorate (35:3)

Thus Australian policy-makers can expect that, as the GFC's effects are felt, the health services sector generally may be unable to cope with the effects of the economic downturn as more people turn from privately funded healthcare to the already overstretched public healthcare sector. Dental care is a pointed example of this: deferred dental care results in emergency hospital admissions. Pharmaceutical price movements are also predicted to exert upward pressure on drug prices with possibly serious cost implications for Australia's public health system (28). The strain on Australia's public healthcare sector is likely to have consequent 'knock-on' effects such as increased waiting times for essential surgery. Other effects include the indirect effects of likely constraints in capital expenditures for construction and maintenance in health services which too often have poor material infrastructure in rural and remote areas and which rely proportionately more on public investment in the absence of private health service providers. This will be unhelpful to making rural and remote healthcare workplaces attractive destinations for health and allied health practitioners, in a context where serious workforce shortages persist (44), including in critical areas such as maternal and neonatal care.

However, it is difficult to predict how rural and remote health workforce shortages may be affected by the GFC. For example, the Report on the Audit of Health Workforce in Rural and Regional Australia showed that 'though there have been some improvements in the availability of GPs in remote areas, the supply is significantly below the national average and the gap in recent years has not decreased' (44:12). Expected large increases in the health workforce through government creation of more places may not result in hoped-for movements of qualified professionals to 'the bush' if economic drivers work to keep them away from particular rural and remote regions also decimated by climate change, making these destinations present unattractive career and family prospects to health professionals. On the other hand, there are indications also that the decline in retirement savings has directly affected a large proportion of health professionals, such as GPs, who plan to delay their retirement,(8) which could be helpful to the rural and remote workforce in the shorter term.

Such effects may be observed even though the Australian government has not decreased its overall spending on health in 2009-2010. The fall in GST-based payments to states may affect state expenditure as demand for services increases (17).

Clearer information about the effects of the GFC on Australians' healthcare utilisation is emerging. For example, a survey of a sample of 806 people in Australia found that 25% of them have either avoided or delayed visits to their healthcare professional in response to the GFC and 9% have stopped or reduced their use of prescription drugs (8). While parents tend to make frontline sacrifices for their children, this trend raises important questions about the 'knock-on' effects of poor compliance to healthcare advice among disadvantaged families. Unfortunately, sound policy-making for rural and remote communities is greatly hampered in Australia by the absence of timely data on a regional basis for health services utilisation.

However, available studies suggest that in Australia, on average, indigenous people use health services much less than the rest of the Australian population, despite their higher mortality and morbidity (45). This means that they and their children may be particularly vulnerable to problems with the quality and access of health services in the wake of the GFC. The fact that there is a good relationship between the income of non indigenous peoples and their use of health services (45) suggests that Australia will see shifts in health service use shaped by falling incomes that will further erode efforts to make gains in indigenous child health.

Conclusions

This paper has suggested that the GFC and climate change will continue to interact in rural Australia to affect the health outcomes of those communities, particularly vulnerable groups such as children. It would be unfair to suggest that the Australian government has not been very active in rural Australia in response to both the GFC and climate change. To date the policy responses to the GFC have centred on national level financial intervention and public economic stimulus, coupled with employment and education programs for those who have lost their jobs (14). The closely interwoven nature of the GFC and climate change in rural Australia has been recognised and the Australian government's responses have targeted both: for example, productivity capacity-building in agricultural industries that includes preparing them for climate change. Yet there is much work to be done to make a difference to vulnerable groups such as rural children.

A number of directions for rural child health policy can be extrapolated from the scattered evidence about the GFC and climate change.

The first direction relates to the importance of local community policy responses, including local council responses (14). Upskilling councils to act effectively across the full range of strategies for building community resilience in the face of the GFC and climate change will be critical. This includes their role in building health and allied health facilities in their region. For example, councils can be active in developing appropriate healthy infrastructure such as transport solutions that reduce reliance on fossil fuels, in turn decreasing reliance on global markets. Not only that, but, in line with OECD policy briefs, (46) the Australian experience of the GFC has stressed the importance of better articulation of knowledge and integration of services at the micro (local), meso (regional) and macro (national) levels (14).

The second related direction emerging from this evidence is about the importance of ensuring that the three pillars of the present government's approach to regional development (infrastructure, education and business development) do not become silos (14) that exclude a health focus, particularly for disadvantaged groups such as rural children. The different patterns of interaction between the GFC and climate change has meant that in each region different suites of services may be needed to respond to the needs of different groups. This direction for health policy advocacy involves the rural health sector being visible in economic reform discussions and economic policy development. In the wake of the GFC, it is certain that advocates for rural and remote health also need to 'be at the table' of economic reform at every level of policy reform: micro, meso and macro (28). The major implication of WHO's Commission on the Social Determinants of Health is that effective health advocacy for rural and remote communities must involve championing a 'social determinants of health' approach at all these levels of policy-making, targeting specific services and disadvantaged groups with nuanced data (2,20).

Such efforts will be hampered by the gaps in evidence that this paper has highlighted. While there is much evidence on the socio-economic determinants of health, and the effects of unemployment, there is little on how to make a difference to the long-term health impacts of unemployment and under-employment and other aspects of recession (8). There is also emerging evidence of the separate effects of the GFC and climate change on health, but little available on how the two interact to shape health and what policies will be effective. Even less is known about how children within groups most affected by interactions between climate change and the GFC will have their health affected in the long term in particular regions. Such research gaps suggest the importance of prioritising research that can make a difference to regionally responsive policy advocacy. The WHO consultation on the GFC and health concluded that 'strategies to mitigate the impact of the financial crisis need to be seen also as opportunities for reform—in the way services are both financed and organized'(35). Researchers and policy-makers in Australia will want to scrutinise approaches for responding to the GFC being developed in other countries, including in papers from, for example, the WHO European Regions April 2009 Oslo meeting (http://www.euro.who.int /healthsystems/econcrisis). This forum noted that data on the impacts of the GFC on health are difficult to compile and analyse in forms useful to policy-making (47). The WHO European Regions has also developed a set of recommendations for member states that prioritise this 'real-time' research support for policy-making. It suggests the importance of research approaches based on community consensus-making and building influential policy networks across the sectors to advance sustainable, environmentally sound economic development for healthy communities (47).

Two sentinel documents need to drive the research of the future: the research questions identified by Research Australia in Australian financial crisis: implications for health and research (8) and those identified by the National Climate Change Adaptation Research Facility Human health and climate Change: national adaptation research plan (19). Both these documents point to the importance of regionally responsive research that focuses on intersectoral policy development. Their calls for regionally responsive research that can make a difference to intersectoral policy and services development, particularly for complex issues of disadvantage, are consistent with a long tradition of public policy research. This tradition includes the 1998 Independent enquiry into inequalities in health which noted that 'the more a potential intervention relates to the wider determinants of inequalities in health (i.e. 'upstream' policies), the less the possibility of using the methodology of a controlled trial to evaluate it' (1,17).

The two ostensible 'causes' of unequal health outcomes of Australians in the 21st Century—the GFC and climate change—will need a new style of health services-oriented research that engages with the wider determinants of health. Yet, as noted in the Research Australia report, the National Health and Medical Research Council spends only 4.2% of its funding on health services research (48). This is consistent with the picture in America which spends a tiny portion (1.5%) of funding for biomedical research on health services research (49). In short, the real problem for sound health policy-making is not that we need more research. The problem is that we do not have the right kind of research.

The health policy work of the rural health sector is hampered not only by the fact that Australia does not have a rural health policy research institute. It is also hampered by a lack of regional level climate change and health impact assessments that can begin to help articulate data for policy from the local to the regional to the national level of health policy decision-making. Development of such approaches is ongoing in the work of the World Health Organisation, however, as yet there is not a standardised tool that can help chart the effects described in this paper.

Thus the third key direction for health policy advocacy by the rural health sector is to drive reform of Australia's research agenda in a way that prioritises our impoverished health services research agenda.

The fourth critical direction for health policy advocacy in the rural health sector lies in the questioning of values that have led to unhealthy outcomes. The GFC has created a seachange in the debate about health and economic well-being. Many people, including health policy researchers, are asking how governments globally have found $5 trillion to bail out the financial sector in an age in which policy-makers have been unable to find funding for many critical health priorities (2). Such questions about values will be important to rural and remote health agendas as governments engage with the groundswell of community opinion that better human health will need a fundamental shift in the values underpinning society (5). As Marmot has noted:

> A model predicated on global economic growth with consequent rise in greenhouse gases and the obscene income inequalities we have seen within and between countries cannot be justified on moral grounds. Given the current state of affairs, globally, it cannot be justified on pragmatic grounds. It is time for a new plan that has equity at its heart (5)

The fifth and final direction for health policy advocacy for the rural health sector lies in developing an explicit rural health policy. Now more than ever, Australia needs a rural and remote health policy with sentinel indicators, agreed on at state and federal levels (50)—one that engages with the challenges presented by the GFC and climate change. It should include explicit indicators for rural child health. Such a policy document could help bring integrated responses to many of the challenges for rural child health identified in this document.

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Chapter 19

AUSTRALIA, "LUCKY COUNTRY" OR "CLIMATE CHANGE CANARY": HER CHILDREN'S FUTURE

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Human health is a function of multiple determinants. Whilst bio-genetics may be somewhat immutable, we can influence the social and environmental conditions that determine health status. This chapter examines the impacts of climate change super-imposed upon decades of rural neglect, and upon rural living in a naturally difficult environment. The demonstrated manifestations of these are poor health outcomes, which renders rural children in Australia especially vulnerable to climate change. Here we propose to consider the specific features behind this vulnerability. Agriculture in Australia has long faced challenges due to the extreme variability in existing climate. International commodity market fluctuations and policies of economic rationalism have created a set of rural disadvantages that has driven many farmers off the land. Climate change is predicted to further exacerbate this trend by increasing the frequency and intensity of heat waves, droughts, fires and floods. Recent weather patterns indicate that climate science predictions are already emerging. Survival of many rural communities depends upon local agricultural prosperity, such that downturns reverberate throughout regions. Yet despite the charm of country living, rurality has become an un- healthy determinant in Australia, across multiple parameters. Concerns over future viability of farming are generating physical and mental health problems among farming families. Once responsible for Australia's reputation as being the "lucky country", Australia's agricultural sector is now in danger of morphing into a "climate change canary", an early casualty of climate change. Rural Australia is in real peril, and rural children are especially

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vulnerable to becoming despondent about their future. Options exist to not only salvage Australia's rural future, but to engage rural communities in mitigation; however this requires commitment to pro-active and pro-rural climate change polices. As of mid 2010, such foresight has yet to appear on the political agenda, instead, we see policies promoting abandonment of rural industries.

INTRODUCTION

We once called Australia the 'lucky country' that 'rode on the sheep's back'. Decline of the wool industry and widespread rural downturn, coupled with climate change havoc are now threatening survival of Australian rural communities. Unlike other countries, Australia moved away from subsidizing agriculture in the belief that the strong will survive. Of particular concern in Australia is that climate change will intensify the rural contraction and service withdrawal witnessed over recent decades, result in widespread financial hardship and exacerbate existing social and health disadvantages

Most Australians enjoy a western lifestyle yet their natural environment shares more features with developing nations. With a land mass similar to that of the USA, it is Australia's heightened sensitivity to climate change that sets it apart from Europe, the United Kingdom and North America. Long characterized as a 'land of droughts and flooding rains', the natural, or rather background Australian climate is noted for its variability and extremes. Natural climatic variations have a very broad range, yet recent weather patterns are breaking long held records by uncharacteristically large margins, and climate change scenarios predict further exacerbation of these existing extremes. Much of the Australian farmland is classified as 'marginal' with minimal reserve capacity to absorb further stressors. For this reason Australia has been categorised as more vulnerable to climate change than any other developed country.

That especial vulnerability is examined in this chapter. We begin with an examination of the particular characteristics of Australian environment, and their influence upon rural people and communities in Australia. We explore the current struggle faced by rural people and communities in Australia against a highly variable climate in a harsh landscape against the background of unsupportive politico-economic responses which underpin the existing disadvantage (social and health), We then consider how this present disadvantage plus future climate change impacts are likely to bring to livelihoods, social well-being and human health. Of significant concern is that rural children are already witnessing this struggle and community decline. Responding positively to adversity is a hallmark of the Australian bush psyche, but we argue that the unprecedented nature of climate change, overlaying the pre-existing vulnerabilities, and current policies pose serious challenges to rural viability, rural resilience and wellbeing. As these changes unfold, it is the children who will be most impacted.

AUSTRALIA - DEFINED BY HER DISTINCTIVE RURAL LANDSCAPE

'Rurality' in Australia is defined by her distinctive landscape and climate, as their unique and powerful influences determine the life and characteristics of people inhabiting her. An understanding of how climate change will affect this nation requires first, an appreciation of these distinctive features of this remarkable land.

Physically isolated between the Pacific and Indian oceans, a third of the continent lies within the tropics and a third is desert with a rainfall less than 200mm per year. Australia's largely unique wildlife and flora evolved to accommodate these geographical and climatic extremes. Indigenous populations crossed the relatively shorter sea voyages from the north during ice-ages 60,000 and again 40,000 years ago (1). Despite their long habitation here, development of formal agriculture was prevented by a lack of domesticable fauna and flora, thermal extremes, highly variable rainfall and the thin, friable top soils that harbour high levels of salinity (2). Survival was possible through limiting population to small nomadic population groups who sourced food supplies via hunting and harvesting of native foods, and by using fire as a land management regime. Indigenous Australians carry a deep spiritual and cultural attachment to the land, and survived by understanding and respecting the land that offered precarious and scant supplies of water and food. Over exploitation of these limited resources would have lead to thirst and inevitable starvation.

Today, Australia is wealthy nation living on this old, large, dry continent. Post the British invasion in 1788, immigration long remained pro-British, however, the Australian population is now becoming increasingly multi-cultural, and increasingly urbanised. One in four Australians was either born overseas, or has a parent born overseas, although cultural diversity is less pronounced in rural areas (3). Low rainfalls limit population carrying capacity, hence Australia's population density ranks 233rd of 239 countries, and 77% of Australians live within 50 kilometres from the coastline, predominantly the East and South-eastern coasts, where rainfall is somewhat more frequent and more predictable (4).

This clustering around the coast leaves most of the inner, northern and west coast regions sparsely populated. For the purposes of allocating services and resources, the Australian Standard Geographical Classification (ASGC) allocates one of five remoteness categories to areas depending on their distance from a range of five types of population centres. Areas are classified as Major Cities, Inner Regional, Outer Regional, Remote and Very Remote (5). This paper classifies as 'rural', all those who live outside major metropolitan centres, and we include rural coastal zones, as these communities are commonly dependant upon non-urban industries for survival.

RURAL AUSTRALIANS

Population exodus from the agricultural sector, and influx from forestry and tourism, and more recently a mining, boom, now creates a mix of rural economic enterprises. All are potentially deeply affected by climate change. Here we particularly focus on the distinctive characteristics of Australian agriculture, as these best demonstrate the impacts of climate change.

At the 1911 Census, 42% of the Australian population were living in rural areas, however by 2006, this figure had fallen to 12%. With the inclusion of regional towns, this figure climbs to 6.5 million people, or 32% of the population (4). At 30 June 2007, there were an estimated 4.1 million children aged 0–14 years in Australia (2.1 million boys and 2.0 million girls), almost one-fifth of the total population (6) Similar to other western countries, fertility fell during the 10 years to 2008, the proportion of children (0-14 years) decreased by 3 percentage points from 22% to 19%.(3) Two-thirds of Australian children aged 0–14 years lived in Major cities in 2006, and a further one-fifth lived in inner regional areas, whereas only three per cent of children lived in remote and very remote areas (6).

According to the June 2006 National Census, the estimated resident Aboriginal and Torres Strait Islander population of Australia was 517,200, or 2.5% of the total Australian population (7). Noteworthy is their younger age profile, with a median age of 21 years compared with 37 years for the non-Indigenous population, and their significantly poorer health status. The Indigenous proportion of the population increases with remoteness.

In 2006, over half (53%) of all Very Remote areas were classified as being in the bottom quarter of Australian socioeconomic areas. Similarly, only one in fifty of these areas were in Australia's top quarter (see table 1) (8). People living in more inaccessible regions of Australia are disadvantaged with regard to educational and employment opportunities, income, access to goods and services, and in some areas access to basic necessities, such as clean water and fresh food. Young Australians continue to leave rural areas, many leave for education, and then for jobs. Over a quarter of people leaving country inland areas in 2006 were aged 15-24 years. The loss of young people makes it difficult to sustain population levels in these areas (4) and reflects the lack of optimism.

Table 1. Selected characteristics of population, by remoteness areas, 2006.

	Major cities	Inner regional	Outer regional	Remote	Very remote	Australia
Total population living in each area	68	20	9	2	1	100
Indigenous population living in each area	32	22	22	9	15	100
Population in each area who are indigenous	1	3	5	13	45	2
Areas in highest SES quartile	34	14	8	10	2	26
Areas in lowest SES quartile	20	28	33	26	53	24
Adequately fluoridated water supply	81	39	24	30	20	49

Source: Australia's Health 2008. AIHW(8)

CURRENT VULNERABILITY OF RURAL COMMUNITIES IN AUSTRALIA

The following sections describe the challenges and the multiple vulnerabilities associated with rurality in Australia.

Early European explorers, such as Hartog and Darwin, recognized Australia's geophysical limitations and described her landscape as 'hostile', and incapable of producing the wealth of the United States (9). Unlike Europe and America, Australia lacks the deep fertile soils formed by the weathering action of glaciers (10). Agriculture was never going to be easy in Australia and at best success would be short lived, and cyclical. Yet despite the harsh conditions, agricultural management practices imposed on this continent were originally developed to suit a much different place – a wet and fertile landscape (11). With European settlement came the direct importation of agricultural practices that had proven successful in the home countries. Unfortunately, most of these are ill-suited and are degrading the environment at a rate estimated by the Australian government at $1 billion per year (12).

Australia's rainfall patterns are fourfold more variable than Russia, threefold more than the United States, and more than double that of New Zealand, India and the United Kingdom (see figure 1) (13). Such significant climate variability brings repeated extreme weather events, cyclones, floods, droughts, and makes the Australian environment prone to natural climate induced disasters. Coupling this inherent climatic variability with poor, hyper-saline topsoils makes survival difficult for all but the most hardy species, plants and animals alike. Populations whose livelihoods are inextricably linked with the environment (such as primary production), are characterised by their stoicism, determination, self-reliance and resourcefulness (14) Rural people identify with this Bush Culture and are proud to distinguish themselves from their city counterparts (15).

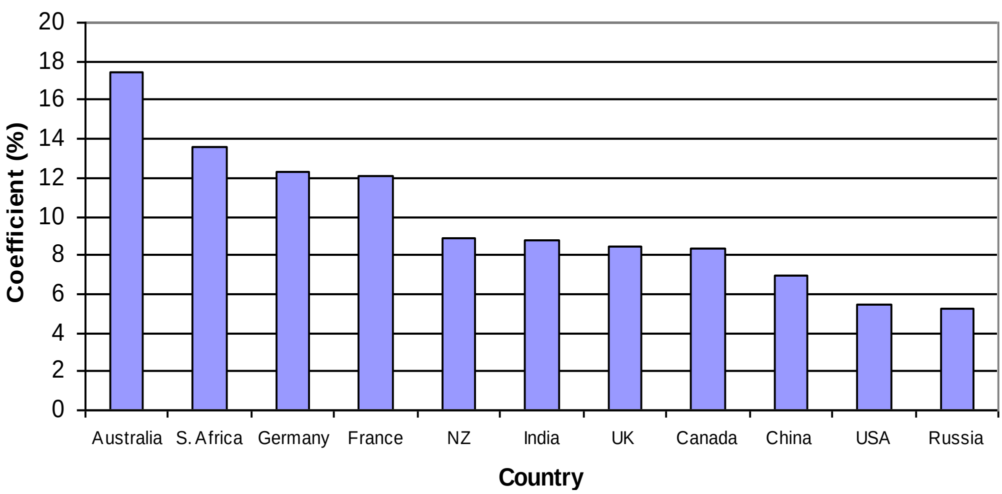

Figure 1. Country comparisons 100 year rainfall variability.

With irregular rainfall patterns, water has therefore historically been a primary concern in Australia. Whereas sparsely populated northern Australia receives monsoonal rainfall, about 80% of the country has an average annual rainfall of less than 600 mm; and over one-third has an annual average of less than 200 mm. Excluding Antarctica, Australia is the driest continent on Earth (16). Unlike other lands, most Australian rivers and groundwater systems flow inland. There is little gradient or fall, so river flow is relatively sluggish which allows for more evaporation and limits their removal of salt from the continent. The low and sporadic rainfall patterns prompted attempts in the 1960's to 'drought proof' the country by building large storage dams. The total storage capacity of Australia's equates to 3.8 million litres per head (17), more than any other country (18). Yet with diminishing rainfall across southern parts of Australia, and growing populations, this is now proving insufficient to meet rising demand. Storage levels have reached dangerously low levels, all capital cities are on water restrictions, and many towns have periodically run out of water. The Lachlan River, which supplies 14% of NSW agricultural production, and 100,000 people, was predicted to run dry in February 2010 (18). Lower reaches of the river system were dry before summer rains filled the capacity to 7.2%. Many areas of Queensland, New South Wales, Victoria and South Australia have not received their irrigation rights for many years, parts of Victoria remain gripped by the most severe drought on record, which has now lasted for nearly 14 years. Critical water planning measures have now been implemented in all States, with water recycling and desalination plants rapidly coming on-line across the nation. However, these will predominantly supply urban centres (17).

Government polices further degraded the fragile Australian landscape. In the agricultural sector, damming of rivers and development of large scale irrigation schemes over past decades opened up areas of inland Australia to agricultural activities which otherwise would not have been possible. Land clearing of timber and scrub to allow extensive grazing of native grasses was actively encouraged, and in some areas, enforced by Governments, even in the semi-arid regions. Land Acts of 1910 to 1961 prohibited vegetative regrowth on cleared land (19). By June 2006, 442.8 million hectares (mill. ha), representing about 58% of the total land area was devoted to agricultural activity. In south-eastern Australia, a drying trend since 1995 has deprived farmers of their water allocation and prompted the establishment of water trading amongst farmers, whereby irrigation water rights are sold to farms yielding higher returns on their water usage.

Amid the global food crisis of 2008, Australian rice growers were selling their water rights to wine makers (17). Whereas it is difficult to justify growing rice in a dry climate, Deniliquin (mid-southwest NSW), held the largest rice mill in the southern hemisphere; the incredulous farmers in the area questioned policies that prioritised Chardonnay production when the world was short of food staples, and 1.2 billion people were undernourished. This example brings into question narrow locally focussed market-driven policies in a warming world where food insecurity is likely to deepen. As one of the six net food exporting countries, it could be argued that Australia has a responsibility to the world's hungry, ignoring downstream effects can reek unpredicted consequences, and exacerbate global inequities.

ECONOMIC VULNERABILITY

Ninety percent of Australian farms are family owned and operated, and most are inherited from previous generations. For agriculturalists, connection with the land is therefore multigenerational and deeply felt. Factors defining rural living include withstanding the major environmental challenges characteristic of this ancient and distinct landscape, the agricultural-environmental interface. Local climate and geophysical landscape determine the feasibility of particular industries, the success of which depends on reliability of climate, level of environmental degradation and rural economics (primarily driven by Australian rural policies and international commodity prices).

Despite the natural environmental impediments, Australian farmers have historically enjoyed periods of profitability. The large available land mass, ingenuity, and willingness to adopt modern practices such as land clearing, water storage and irrigation, application of chemicals and investments in new crop varieties, plus years of high commodity prices have contributed periodically to high incomes. But environmental and economic problems from the mid 1970's have taken their toll, in economic and health terms (15). Chemical reliance drives the need for further chemicals. Agricultural chemicals and fertilisers accounted for about 25 per cent of average grains industry cash costs in 2007 (grains industry includes wheat and other crops and mixed livestock-crops industries). In 1997-98, this was 17 per cent and only 6 per cent 20 years ago (1987-88) (20).

Around 65 per cent of agricultural production is exported to international markets, making Australia's agricultural establishments 'price-takers' on world markets (21). Between 1974 and 2006 Agricultural productivity climbed at an average of 2.3 per cent per year, against a fall in real returns of 2.4 per cent. By 1990, farmers' terms of trade were at their lowest point since the Great Depression, and as farm debt increased, farmers have been forced off the land. The number of farms decreased from 205,000 in the early 1950's (22) to around 136,000 in 2009,(20) and this was accompanied by a loss of over 120,000 from the rural workforce. This decline in rural populations has accompanied a loss of political influence, and a disappearance of pro-rural policies.

The worst drought on record has persisted for more than 14 years across southern parts of Australia. Government reports indicate 'negative farm business profits' are widespread (80% of all Australian farms in 2006, 70% in 2007 and 69% in 2008) and a national average farm loss of $21,000 in 2007-2008. That year, the average annual loss per farm in Tasmania was $67,000, $45,000 in South Australia and $29,000 in Victoria (20). Such continued losses are not sustainable and the health effects are pronounced.

In contrast, Australia's mining sector is highly profitable. Demand for Australian minerals generated by China's rapid growth created a mining boom in selected rural areas. Mining employment and wealth has surged since 2001 in those regions. High mining wages has disrupted local pricing, and translated to rapidly rising housing costs, which in some communities, have tripled in three years (23). Rural families have reported being 'priced out' of their own communities, as those not employed in mining found their incomes devalued. Employment opportunities were welcome but disruptions to local economies, town culture and the environment are not. When rural economic statistics are aggregated, this economic boom serves to overshadow the real plight occurring in much of rural Australia.

POLICY RESPONSE

An Exceptional Circumstances program provides financial assistance to farmers facing hardship. However the Federal Government has re-evaluated droughts, which, due their increasing frequency, no longer constitute an 'exceptional circumstance' (24). The Australian Bureau of Agriculture Research Economics (ABARE) is a key Federal Government Agency that provides expert advice on rural policy. The quote in Box 1 from their 2009 June Quarter Commodity Report demonstrates an understanding that primary production in Australia is facing serious challenges (25). However, unlike the UK, EU and USA, the Australian Government is not aiming to protect the livelihoods of farmers, but rather is applying market mechanisms to "encourage less viable users to exit the industry". In essence, Australia's policies are actively driving farmers into penury.

Withdrawal of farming subsidies is a long-standing federal policy of this country, which in part, has contributed to the past definitions of 'success' of Australian farmers. Primary producers were reported to be 51% more productive than their United States counterparts, 155%more productive than their British farmers, and 220% cent more productive than German primary producers on a per capita basis (26). Only large holdings could survive, so farmers bought out their neighbours. The relative 'success' of Australian farmers, measured in terms of output per farm, therefore comes at a high human cost. These past deliberative policies contributed significantly to the pattern of rural hardship, a lowering of socio-economic status, health decline and resultant population exodus. As a policy mechanism, it is unsustainable to have a perpetual (over many decades) economic downshifting and removal of the lower layers. It is also wicked social policy.

Box 1. Government policy to encourage farmers off the land.

Australian irrigators face a number of economic adjustment pressures. In addition to continued declines in real commodity prices, there will be pressures from potential reductions in access to irrigation water because of lower water inflows as a result of climate variability and change and redirection of flows to environmental uses. Costs of water and water delivery services are likely to increase. The long term viability of irrigated agriculture will depend on the ability of the industry to adapt to these pressures.
Costs associated with reduced access to irrigation water can be mitigated if the restrictions on interregional trade are removed (where these restrictions are not based on environmental grounds). Removing restrictions on interregional trade will facilitate adjustment and assist risk management by ensuring that irrigators who value water most get access to it. As a result of interregional trade, the higher price for water received in some regions will encourage less viable users to exit the industry and speed up the adjustment process.

Source: ABARE Australian Commodities. June Quarter. 2009(25)

RURALITY: AN UN-HEALTHY DETERMINANT IN AUSTRALIA

Health is not evenly distributed in Australia. Lower socio-economic groups, rural populations and Indigenous peoples experience significantly pooper health status than the national average. The rural-metropolitan health differential first attracted political attention in 1993, and prompted a raft of strategies. The efficacy has been minimal, as the entrenched disparity persists.

The health of rural Australian children is complex, and subject to multiple interconnected factors (27). For example, air pollution is less in rural areas, but exposure to biological dusts and agricultural chemicals is considerably higher. Limited access to health care and lower socioeconomic factors place significant burden on rural health and wellbeing, yet the higher levels of reported social capital is protective (28).

Australian households with children in the lowest socioeconomic status (SES) areas were 3.6 times as likely as in the highest SES areas to be exposed to tobacco smoke in the home in 2007. Adults living in rural areas were 40% more likely than those in Major cities to consume alcohol in quantities that risked harm in the long term, which increases the likelihood of more frequent alcohol use during late adolescence, and risks future morbidity and mortality in the future.

Fewer health providers, notably specialists practise outside the major centres, making access to health services problematic for rural populations, despite decades of polices to increase rural doctor numbers (29). In regional and remote areas health, facilities were less likely to be accredited. Mortality in regional and remote areas between 10% and 70% higher than Major Cities (30). Policies to reduce the gap have had minimal affect, and these figures have not improved since 1997–99 and 2002–04 (30). It is difficult for the health sector to effectively redress the health impacts of social disadvantage. The very poor health status of Indigenous Australian, reflected by the 17 years difference in life expectancy, significantly impacts upon these data. (According to recent data, the life-expectancy gap has narrowed, however different criteria were applied, which casts doubt on the validity of trend analysis) (31).

Despite access difficulties, rates of hospital separations for acute care were significantly higher for residents of all remote areas than for residents of major cities, increasing from 1.1 times as high in Remote areas to 1.6 times as high in very remote areas (5). This is viewed to be a function of delayed management of treatable conditions. In 2006, babies from the lowest socioeconomic status (SES) areas were almost 30% more likely to be of low birth-weight, and born prematurely with concomitant long term health and disability impacts than those from the highest SES areas. In 2005–06, people with disability living outside Major Cities were significantly less likely to access disability support services than those living within Major Cities, and children living outside major urban centres tend to have more decayed, missing and filled teeth than those living within them (6). In children aged 2–17 years, the national prevalence of overweight and obesity is 17% and about 11% respectively (32), however these figures are also higher in rural areas (6). The rate of new cases of Type 1 diabetes in children is increasing in Australia and is high compared with that of other countries, at 23 per 100,000 children (8).

On average, suicide is responsible for 1.7% of all Australian deaths annually, four-fifths (79%) were male. In regional and remote areas, death by suicide rates were 25–40% higher than in major cities. Suicide statistics 'mask' the individual and their personal struggle. The suffering of a suicidal person is much more significant than an analysis of statistics can reveal, and the impact upon the family can be profound (33). Interpersonal violence was responsible for 0.2% of Australian deaths annually, yet death rates were 35% higher outside major cities (30).

These can be symptomatic of stress and depression at diminishing economic viability (34). Unemployment and underemployment affect men and women differently. Whereas women identify themselves as nurturers, the glue that holds families together, denying men of their breadwinner role, leaves them with no clear 'role' for themselves in society, and their self esteem suffers. This attitude is also reported among rural young men and adolescents who are considering their future prospects for supporting families (33). Children's mental health is suffering (35).

The report "Suicide in Australia: A dying shame" by the Wesley Mission, and LifeForce Suicide Prevention Program, argues it is widely accepted that small communities, with populations of less than 10,000 are no longer economically viable, as we witness farm repossession, business and industry closures, the removal of medical and educational services, and the exodus of people to larger commercial centres (33). Children will be daily witnessing this situation unfold among their families, relatives and friends.

The relationship between the health and wellbeing of children and the environment in which they grow up is now well documented. Children who are raised in supportive, nurturing environments are more likely to have better social, behavioural and health outcomes (6). Similarly, children who have been abused or neglected emotionally or physically often demonstrate poor social, behavioural and health outcomes immediately, and later in life. Victims of prolonged family tensions, abuse and neglect may experience lower social competence, poor school performance and impaired language ability, a higher likelihood of criminal offending, and mental health issues, such as eating disorders, substance abuse and depression (6).

Despite increasing reports of rural mental health symptoms, resilience remains strong in some rural communities (28). Many cling to rural living as a lifestyle choice, preferring not to move to large urban capital centres, which are often viewed as crowded, violent, distrustful, noisy, polluted, and unfriendly. Added disincentives to relocate are limited employment opportunities, and high urban housing costs. Limited options offer little choice, but amplify the stress of decision making.

There remains many positive psychosocial features of country life, which provide for emotional needs, such as deep longstanding friendships, and community recognition and respect which contribute mental health supports. Defining characteristics of rural Australians also offer protection, such as patience, optimism, stoicism, a strong adherence to self-determinism and independence (14). A strong bond exists between rural people, and although competitive, mateship is strong, borne out of distance induced isolation, and the need to assist each other in times of adversity or crisis. These features combine to mould the Australian rural mindset, motivate behaviours, and act as powerful drivers of physical and mental health, and therefore well-being, and hence serve as positive rural health determinants (28). It also explains why, in especially cohesive communities, well-being can prosper despite savage interruptions to farm productivity, and viability. However, concerns now exist over the capacity of community resilience to withstand relentless hardship and added climate change stress (34).

CLIMATE CHANGE IN AUSTRALIA: ARE HEAT, FIRES AND DROUGHT, EARLY EVIDENCE?

Australia's climate change future is already emerging, as extreme events overlay creeping changes. The key findings of the latest research presented to Intergovernmental Panel on Climate Change (IPCC) meeting in Copenhagen in March 2009 stated that current rates of Greenhouse Gas emissions are tracking higher than the worst-case scenario trajectories. Many key climate indicators are already moving beyond the patterns of natural variability within which contemporary society and economy have developed and thrived (36). This is especially grim news for rural people in a hot country such as Australia. Heat, fires and water shortages are the principal concerns for the southern areas of rural Australia where other climate change hazards of cyclones and mosquitoes are in less common.

Since the 1950s, average Australian temperatures have risen by approximately 1°C with an increase in the frequency and intensity of heatwaves and a decrease in the numbers of frosts and cold days (37). Eastern parts of the continent Australia are warming at 0.4°C per decade, and have warmed 2°C since 1957 (38). Record high temperatures were observed in the summer of 2009 across South Australia, Tasmania and Victoria. Victoria reached temperatures of 48.8°C, records were broken by 3°C in Tasmania, and in South Australia a heatwave of 15 consecutive days over 35°C, exceeded that record by 7 days (39). A threshold maximum temperature above which mortality is observed to increase in eastern Australian cities is approximately 28-30°C (40).

Victoria recorded 374 excess deaths, equating to a 62% increase in total all-cause mortality (41). Currently there are approximately 1115 heat-related deaths per year in Australia’s five largest capital cities, and this number is projected to triple by 2020 (42). Rural figures are not known. Australia can therefore anticipate significant increases in heat-related morbidity, especially among infants and young children, due the increase in very hot days. And as temperatures continue to warm, their future is likely to be very hot.

The ubiquitous and highly volatile Eucalypt (Gum Tree) and hot dry weather make Australia the most fire prone country in the world. Bushfires have ravaged rural landscapes, destroyed the aesthetic beauty and removed the incentive for tourist visitation and habitation. Local residents suffer solastalgia, grieving for the lost landscape, loss of housing, infrastructure, human lives, lifestyle, stock, wildlife and pets (43). The effects ripple through the communities. These losses further exacerbate economic downturns resulting from the drought and a decade of economic rationalism. The result intensifies rural vulnerability to stress and subsequent mental health issues (44).

Australian bushfires are increasing in frequency and intensity. In the 100 years to 2008, there were 552 civilian fatalities due to the nation’s fires. During the severe 2002-2003 season, there were 5999 bushfires recorded. In the 2009 firestorm, 173 perished, 61 businesses and over 2000 homes across 78 communities were destroyed (45). Conditions on February 7th 2009 were unheralded, as temperatures approached 50°C, the flashpoint of eucalyptus vapour, there was extremely low humidity (<10%), and winds exceeded 95km/hr. The trees exploded. Whereas no specific event can be attributed to climate change, such conditions are both unprecedented and entirely within climate change predictions. The alarming feature is that these conditions were not anticipated to emerge so soon. Fire control systems were overwhelmed, which prompted a Royal Commission and triggered the establishment of a new ‘catastrophic’ fire risk category (45).

Bushfire fatalities demonstrated the heightened vulnerability of women, children and the elderly. While men are most often killed outside, while at work or attempting to protect assets, most female fatalities occur while sheltering in the house or attempting to flee too late. The number of men killed by bushfires has decreased; however, this is not the case for women and children, who in recent years have died in relatively high numbers (46).

Bushfires bring additional health risks. During the 2006-2007 bushfires Victoria air quality monitoring sites peaked at four times the National Environment Protection Measure

24-hour standard. Analysis of the measurements showed high concentrations of carbon monoxide, nitrogen dioxide, and ozone, in addition to fine particles between 0.1 and 0.5 μm diameter, largely composed of non-volatile organic material (47), which are easily respired and can cause significant health impacts. Australia's asthma rate is high by world standards, and these conditions exacerbate attacks.

Climate change impacts will not be limited to agriculture, other rural industries forestry, fishing, tourism and mining will also be affected. Forestry industries face many threats, primarily deaths of trees and bushfires, in addition to a growing resistance to removing a carbon sequestration mechanism. Commercial fishing (globally) is facing significant threats, not least among overfishing, through warming of the seas, acidification and the potential collapse of the marine food web (48). Probably more so than many other nations, Australian tourism relies on natural resources and to this end, is highly vulnerable to climate change. The Great Barrier Reef is under serious threat of dying (49), it contributes to more than a third of the region's gross revenue and 30,000 jobs (50). Townships dependent on inland water sports on reservoirs have collapsed as capacity of large dams dropped to 5%. The ski fields are disappearing (51), the majority of the Victorian Alpine forests (3 million ha) burned during the 2003, 2006 and 2009 bushfires, causing a 50% decrease in tourism (52).

This limits capacity for other industries to provide a buffering effect to rural communities during economic downturn.

AUSTRALIA'S RESPONSE TO CLIMATE CHANGE

Considering the heightened vulnerability of Australia to the impacts of climate change, the political and popular response appears counterintuitive. Climate change is a function of population expansion and resource consumption, yet in a water stressed environment, the Australian government is promoting significant population growth.

Fossil fuel industries, predominantly coal, harness considerable political influence due their contribution to national exports (37% of total) and gross domestic product (GDP) (53). Australia ranks as one of the world's leading mining nations, with the world's largest demonstrated resources of brown coal, and is the world's largest exporter of black coal. Overall, mining activity accounts for around 8% of GDP, and has contributed over AU$500b directly to Australia's wealth during the past 20 years. Coal contributes AU$55 billion of this sum.

Recent studies by the International Consortium of Independent Journalists, conducted the through the Center of Public Integrity, revealed the extent of lobbying by big polluting companies to thwart Greenhouse Gas Emission programs (54). Lobbying has been so successful in achieving influence that neither politician nor mainstream media outlet has been game to mention their activities. Australian coal companies will pay 80 cents or less per metric ton of coal for their emissions. Their claim, that any additional cost incursions will close mines and loose jobs are questionable at best, when coal is currently selling for between around AU$70 and AU$150 per metric ton on exports markets. This lobbying has been particularly effective in Australia, where the proportion of Australians who perceive climate change as a serious threat has decreased to 52% nationally, and only 43% among men (55).

With the nation evenly split, climate change remains a highly charged political issue in Australia, as the Emission Trading Scheme proposed by the Federal Government included $12.5 billion in subsidies to the 20 major greenhouse gas emitting companies (56). Meanwhile the political party representing farmers' interests publicly denies global warming or that there is a significant anthropogenic component to the current climate variability being observed. The deep divisions on this issue split the conservative Coalition Party on the eve of the December 2009 Copenhagen Climate Summit, where the Liberal Party Leader was replaced by a climate sceptic (57).

Australia also has plentiful wind and solar resources, in addition to significant geothermal energy potential. Carbon sequestration in soils, afforestation offer further options for rural communities to retain rural lifestyles, to engage in economically viable pursuits and contribute to climate change mitigation strategies. Reports suggest that regional Australia stands to substantially benefit from clean energy jobs that could be created if national climate change policies are put into place. Clean energy projects and business proposals awaiting renewable energy target and emissions trading scheme, are forecast to create about 26,000 new jobs, many of them in regional Australia, which would inject around $10 billion into local economies in regional Australia (58). In the absence of government incentives, paralleled by heavy subsidization of the goal and gas industries, investment in renewable energies in Australia has been slow, and meanwhile, the rural decline continues.

FUTURE OPTIONS

Rural disadvantage in Australia is exacerbating. Although offering significant advantage over metropolitan childhoods in terms of connectedness and space to roam, lack of services and socio-economic disadvantage of rural living can deprive children their opportunities to reach optimum potential. With forecasts of more extreme heat, more droughts and more fires, and further economic losses, climate change now threatens the existence of small rural communities dependent upon agriculture and tourism.

Without positive policies rural communities across Australia may collapse like a deck of cards. Existing policy responses encourage farming families to exit rather than support rural people to transition into renewable energy or mitigation industries. It is a difficult decision to leave the land, one's home, community, and friends, especially when viable options are limited. It must be especially hard to accept responsibility for farm failure when ancestors survived tough times. The lack of viable alternatives generates significant stress, and children are witness to this stress and experience its consequences.

Lands with barren soils, harsh climates, poor water quality, or unsuitable native flora and flora for domestication or human consumption are unable to sustain large populations. Climate change may well push rural Australia towards that tipping point of unsustainability. Such a scenario will bring heartache and health problems, and it appears that the process may be starting in the Australian bush. Many historical examples demonstrate the decline of civilisations when environmental conditions deteriorate. However, twenty-first century society need not follow that fateful path. The difference is that technology did not exist to prevent collapse of past societies, and it is unlikely they understood the mechanism, nor indeed how to reverse the trend. Today we have that advantage.

The pathway to decline is unlikely to be sudden; en route there would be much suffering and hardship endured by all. Children and future generations will inevitably bear the brunt as climate change conditions unfold. Australia's climate change canaries are those families who rely heavily upon environmental integrity. They are already suffering, whereas they could be gainfully shepherding a mitigation based future. Australia must not sacrifice her rural children.

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Chapter 20

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Chapter 21

About the University Department of Rural Health

The University Department of Rural Health (UDRH) program is an Australian Government initiative. The UDRH Tasmania was established in 1997 and is based in Launceston, in Northern Tasmania and in Hobart, southern Tasmania. It is part of the Faculty of Health Science of the University of Tasmania. The UDRH Tasmania is part of a national network of University Departments of Rural Health - ARHEN (the Australian Rural Health Education Network). The multidisciplinary University Department of Rural Health (UDRH), Tasmania is committed to improving access to health care resources and contributing to improved health outcomes for people in rural and remote areas of Tasmania by:

- Working collaboratively to achieve an adequate, appropriately trained and stable rural health care workforce;
- Facilitating access to appropriate education and training opportunities, resources and ongoing support across the learning continuum, and
- Promoting and supporting a primary health care approach to rural health research and preventative health strategies.

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Chapter 22

About the National Institute of Child Health and Human Development in Israel

The National Institute of Child Health and Human Development (NICHD) in Israel was established in 1998 as a virtual institute under the auspicies of the Medical Director, Ministry of Social Affairs and Social Services in order to function as the research arm for the Office of the Medical Director. In 1998 the National Council for Child Health and Pediatrics, Ministry of Health and in 1999 the Director General and Deputy Director General of the Ministry of Health endorsed the establishment of the NICHD.

Mission

The mission of a National Institute for Child Health and Human Development in Israel is to provide an academic focal point for the scholarly interdisciplinary study of child life, health, public health, welfare, disability, rehabilitation, intellectual disability and related aspects of human development. This mission includes research, teaching, clinical work, information and public service activities in the field of child health and human development.

Service and Academic Activities

Over the years many activities became focused in the south of Israel due to collaboration with various professionals at the Faculty of Health Sciences (FOHS) at the Ben Gurion University of the Negev (BGU). Since 2000 an affiliation with the Zusman Child Development Center at the Pediatric Division of Soroka University Medical Center has resulted in collaboration around the establishment of the Down Syndrome Clinic at that center. In 2002 a full course on “Disability” was established at the Recanati School for Allied Professions in the Community, FOHS, BGU and in 2005 collaboration was started with the Primary Care Unit of the faculty and disability became part of the master of public health course on “Children and society”. In the academic year 2005-2006 a one semester course on “Aging with disability” was started as part of the master of science program in gerontology in our collaboration with the Center for Multidisciplinary Research in Aging.

RESEARCH ACTIVITIES

The affiliated staff have over the years published work from projects and research activities in this national and international collaboration. In the year 2000 the International Journal of Adolescent Medicine and Health and in 2005 the International Journal on Disability and Human development of Freund Publishing House (London and Tel Aviv), in the year 2003 the TSW-Child Health and Human Development and in 2006 the TSW-Holistic Health and Medicine of the Scientific World Journal (New York and Kirkkonummi, Finland), all peer-reviewed international journals were affiliated with the National Institute of Child Health and Human Development. From 2008 also the International Journal of Child Health and Human Development (Nova Science, New York), the International Journal of Child and Adolescent Health (Nova Science) and the Journal of Pain Management (Nova Science) affiliated and from 2009 thw International Public Health Journal (Nova Science) and Journal of Alternative Medicine Research (Nova Science).

NATIONAL COLLABORATIONS

Nationally the NICHD works in collaboration with the Faculty of Health Sciences, Ben Gurion University of the Negev; Department of Physical Therapy, Sackler School of Medicine, Tel Aviv University; Autism Center, Assaf HaRofeh Medical Center; National Rett and PKU Centers at Chaim Sheba Medical Center, Tel HaShomer; Department of Physiotherapy, Haifa University; Department of Education, Bar Ilan University, Ramat Gan, Faculty of Social Sciences and Health Sciences; College of Judea and Samaria in Ariel and recently also collaborations has been established with the Division of Pediatrics at Hadassah, Center for Pediatric Chronic Illness, Har HaZofim in Jerusalem.

INTERNATIONAL COLLABORATIONS

Internationally with the Department of Disability and Human Development, College of Applied Health Sciences, University of Illinois at Chicago; Strong Center for Developmental Disabilities, Golisano Children's Hospital at Strong, University of Rochester School of Medicine and Dentistry, New York; Centre on Intellectual Disabilities, University of Albany, New York; Centre for Chronic Disease Prevention and Control, Health Canada, Ottawa; Chandler Medical Center and Children’s Hospital, Kentucky Children’s Hospital, Section of Adolescent Medicine, University of Kentucky, Lexington; Chronic Disease Prevention and Control Research Center, Baylor College of Medicine, Houston, Texas; Division of Neuroscience, Department of Psychiatry, Columbia University, New York; Institute for the Study of Disadvantage and Disability, Atlanta; Center for Autism and Related Disorders, Department Psychiatry, Children’s Hospital Boston, Boston; Department of Paediatrics, Child Health and Adolescent Medicine, Children's Hospital at Westmead, Westmead, Australia; International Centre for the Study of Occupational and Mental Health, Düsseldorf, Germany; Centre for Advanced Studies in Nursing, Department of General Practice and Primary Care, University of Aberdeen, Aberdeen, United Kingdom; Quality of Life Research

Center, Copenhagen, Denmark; Nordic School of Public Health, Gottenburg, Sweden, Scandinavian Institute of Quality of Working Life, Oslo, Norway; Centre for Quality of Life of the Hong Kong Institute of Asia-Pacific Studies and School of Social Work, Chinese University, Hong Kong.

TARGETS

Our focus is on research, international collaborations, clinical work, teaching and policy in health, disability and human development and to establish the NICHD as a permanent institute at one of the residential care centers for persons with intellectual disability in Israel in order to conduct model research and together with the four university schools of public health/medicine in Israel establish a national master and doctoral program in disability and human development at the institute to secure the next generation of professionals working in this often non-prestigious/low-status field of work. For this project we need your support. We are looking for all kinds of support and eventually an endowment.

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Chapter 23

ABOUT THE BOOK SERIES "HEALTH AND HUMAN DEVELOPMENT"

Health and human development is a book series with publications from a multidisciplinary group of researchers, practitioners and clinicians for an international professional forum interested in the broad spectrum of health and human development.

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- Bell E, Seidel BM, Merrick J, eds. Climate change and rural child health. New York: Nova Science, 2011.
- Bell E, Zimitat C, Merrick J, eds. Rural medical education: Practical strategies. New York: Nova Science, 2011.

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Climate change and rural child health

International aspects

Erica Bell, Bastian M Seidel and Joav Merrick

Climate change is one of the biggest threats to human health in the 21st Century. Many climate change 'hotspots' lie in rural and remote communities. Within these communities rural children represent a most vulnerable group that has been relatively neglected in the climate change research. We have gathered a number of researchers and professionals to write papers for this book with the aim of focussing international attention on the impacts of climate change on rural child health and appropriate responses. This book includes contributions from some of the world's leading climate change researchers, who were asked to explore the implications of their research for rural child health. The chapters offer conceptual understandings, implications for health and allied health practice, and analyses of appropriate policy responses. Authors examine special issues in climate change and rural child health, providing disease-based analyses as well as consideration of education and development issues. The book also offers an examination of country-level issues suggesting the great diversity of impacts and the importance of considering regional effects.

This book offers much in-depth discussion of climate change and rural child health from an international perspective, with contributions from leading international experts.

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