Child Health and Survival in a Changing Climate: Vulnerability, Mitigation, and Adaptation

Chapter · January 2016

DOI: 10.1007/978-981-4585-54-5_34

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Child Health and Survival in a Changing Climate: Vulnerability, Mitigation, and Adaptation

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N. Ansell et al. (eds.), *Geographies of Global Issues: Change and Threat*,
Geographies of Children and Young People 8, DOI 10.1007/978-981-4585-54-5_34

Abstract

The effects of climate change include increased frequency and intensity of extreme weather events as well as adverse changes in air pollution, increased spread of climate-sensitive disease, and heightened food insecurity. All of these effects are predicted to have a significant impact on global mortality and morbidity, and the available evidence indicates that children are most at risk. In order to protect child health, immediate action to both mitigate further climate change and adapt to existing and expected impacts is required. This chapter reviews the existing literature on the health impacts of climate change on children. It identifies children as key stakeholders in action and decision-making for mitigation and adaptation at a variety of scales. It also highlights how child participation in research, policy, and practice will increase the effectiveness and sustainability of solutions for addressing the health impacts of climate change. The chapter concludes with a call for the climate change community to make a more concerted effort to incorporate the needs and capacities of children into its core agenda.

Keywords

Children • Health • Climate change • Hazards • Disasters • Mitigation • Adaptation • Child rights • Child participation

1 Introduction

In the *Climate Change 2014 Synthesis Report*, the Intergovernmental Panel on Climate Change (IPCC) confirms that human influence on the climate system is clear and growing, with impacts observed across all continents and oceans (IPCC 2014). The report states that many of the observed changes since the 1950s are unprecedented over decades to millennia, and it is now 95 % certain that humans are the main cause. In addition, the report finds that the more human activities disrupt the climate, the greater the risks of severe, pervasive, and irreversible impacts for people and ecosystems and long-lasting changes in all components of the climate system. The effects of climate change include increased frequency and intensity of extreme weather events as well as adverse changes in air pollution, increased spread of climate-sensitive disease, and heightened food insecurity (Smith et al. 2014; Watts et al. 2015). All of these effects are predicted to have a significant impact on global mortality and morbidity, and it is increasingly recognized that children are most at risk (Sheffield and Landrigan 2011; WHO 2009a; Xu et al. 2012).

This chapter presents a focused discussion of child health and climate change. It first reviews the existing research on child vulnerability to both extreme weather events and climate-sensitive disease and finds that while numerous uncertainties and knowledge gaps need to be addressed, urgent action to protect child health is required. It then explores the two major pathways for action – climate change mitigation and climate change adaptation. Throughout the chapter, the importance

and value of child participation in knowledge generation and decision-making are emphasized. While children are often viewed as helpless victims of climate change, who rely on others for their health and survival, an emergent literature is highlighting children's capacities for contributing to sustainable and effective action at the global, national, and local level. The chapter concludes with a call for an increased focus on child health across research, policy, and practice and a recommendation for increased child participation across these three domains.

2 Child Vulnerability to the Health Impacts of Climate Change

The health impacts of climate change include increased morbidity and mortality due to more frequent and intense extreme weather events such as heat waves, floods, droughts, and tropical cyclones (Smith et al. 2014; Watts et al. 2015). They also include increasing incidences of climate-sensitive disease such as malaria, dengue fever, diarrhea, and respiratory illness (Smith et al. 2014; Watts et al. 2015). Due to a variety of physiological, behavioral, and social characteristics, extreme weather events and climate-sensitive diseases tend to impact most heavily on children, so it is likely that a substantial proportion of the morbidity and mortality burden due to climate change will be borne by this group (Sheffield and Landrigan 2011; WHO 2009a). In the absence of future projections that focus specifically on children, this section combines data from existing climate change scenarios, future projections of population health, and the current state of child health to highlight child vulnerability to the full range of extreme weather events and climate-sensitive diseases.

2.1 Drought

While a lack of observational data precludes definitive statements about causality, there is mounting evidence that climate change is increasing both the likelihood and intensity of drought events around the world (Smith et al. 2014; Watts et al. 2015). Since 1950, some regions have experienced longer, more intense droughts, and current projections indicate that droughts will continue to intensify throughout the twenty-first century (IPCC 2012). This is expected to significantly reduce yields of staple crops and drive up food prices (Smith et al. 2014; Nelson et al. 2009). In low-income countries, this will ultimately affect food availability and access, which will, in turn, exacerbate rates of undernutrition (Stanke et al. 2013).

The World Health Organization (2009a) asserts that undernutrition in developing countries constitutes the largest single negative impact of climate change and that children will be worst affected. Nelson et al. (2009) estimate that by 2050, declining food security in developing countries will increase child undernutrition by 20 % relative to a world with no climate change, which equates to an additional 25 million children affected. Across the developing world, the impacts of undernutrition on child mortality and morbidity are profound (Black et al. 2013; WHO 2009a).

In 2011, undernutrition was the cause of 3.1 million child deaths or 45 % of all child deaths (Black et al. 2013). In children aged under 2 years, undernutrition also causes stunting (low height for age), a permanent condition which impedes physical, cognitive, and psychomotor development (Black et al. 2013). Several longitudinal studies show that stunting before the age of 3 years predicts poorer cognitive and educational outcomes in later childhood and adolescence and reduced economic productivity in adulthood (Grantham-McGregor et al. 2007; Black et al. 2013). It also has intergenerational effects – the offspring of stunted women typically have a lower birth weight which makes them more susceptible to various forms of illness and disease (Grantham-McGregor et al. 2007). It is estimated that by 2050, declining food security and nutrition may increase severe stunting by up to 55 % in sub-Saharan Africa and 61 % in South Asia which has serious implications for the acquisition of human of capital in these regions (Lloyd et al. 2011).

2.2 Floods

At the global level, floods are the most frequently occurring type of natural hazard and have the largest impact in terms of both fatalities and people affected (Doocy et al. 2013). Between 2010 and 2015, flood events caused 33,616 deaths and affected over 1.5 billion people (CRED 2015). Under most climate change scenarios, more frequent intense rainfall events are expected in most parts of the world, causing more frequent riverine floods in small catchments (IPCC 2012). It is also expected that increasing heat waves, glacial retreat, and/or permafrost degradation will affect high mountain phenomena such as slope instabilities, mass movements, and glacial lake outburst floods (IPCC 2012). It is also very likely that mean sea level rise will contribute to upward trends in extreme coastal high water levels and tidal flooding (IPCC 2012). On this basis, a dramatic increase in flood-related health impacts are expected, unless serious adaptation measures are taken (Smith et al. 2014; Watts et al. 2015).

The immediate health impacts of floods include drowning, injuries, and water- and vector-borne diseases, while the longer-term impacts include mental health issues, malnutrition, and poor birth outcomes (Alderman et al. 2012; Smith et al. 2014). Although these impacts have been observed in both high- and low-income countries, it is clear that the latter bear the global burden of flood-related mortality and morbidity (Alderman et al. 2012). While flood fatality reports are rarely disaggregated by age (Doocy et al. 2013), there is growing evidence that children are at a heightened risk. In an epidemiological study of the 1993 flood disaster in Sarlahi, Nepal, Pradhan et al. (2007) found that the risk of death for those aged between 2 and 9 years was twice that of those aged 15 years and older. Additionally, the risk of death for preschool-aged girls was one and half times that for preschool-aged boys. Children are also more likely to contract and succumb to the waterborne diseases that proliferate in flooded communities, and in regions where food security is volatile, flood-related destruction of crops and livestock can increase rates of child undernutrition and stunting (Fischer-Walker et al. 2014).

2.3 Tropical Storms

Since 1990, tropical storms have killed over 300,000 people (CRED 2015). The deadliest events have all occurred in Southeast Asia: in 2008, Cyclone Nargis in Myanmar killed 138,666; the 1991 cyclone in Bangladesh killed 138,886; and in 2013, Super Typhoon Haiyan in the Philippines killed 4354 (CRED 2015). While climate change is not expected to affect the frequency of tropical storms, it will increase cyclone precipitation rates and maximum wind speed, creating the conditions for more destructive events (IPCC 2012). In addition, sea level rise, coupled with a likely increase in cyclonic wind speed, will exacerbate storm surge and increase the magnitude of coastal inundation (IPCC 2013). Using a spatially explicit mortality model of 577 coastal cities in 84 different countries, Dasgupta et al. (2009) modeled 1-in-100-year storm-surge events accounting for 1 m sea level rise and a 10 % increase in cyclone intensity. Across the 84 countries, it was projected that by 2100, an additional 52 million people and 30,000 km^2 will be affected by coastal inundation.

Like floods, tropical cyclones adversely affect mortality and morbidity through drowning, injuries, and infectious diseases, and there is some evidence that children are at an increased risk (Chowdury et al. 1993). In an epidemiological study of the 1991 cyclone disaster in Bangladesh, Chowdury et al. (1993) found that three quarters of fatalities were children under 15 years of age. They also found that among children under 5 years of age, the death rate for females was 15 % higher than their male counterparts. While not statistically significant, this finding does raise questions about the protections afforded to girls during a disaster event. However, the evidence of children's increased risk is equivocal. For example, in an analysis of hospitalizations for injuries following Typhoon Rananim, which struck the coast of China in 2004, the rate of injuries increased according to age (from 20 per 100,000 for those $<$20 years of age to 75 per 100,000 for those $>$70 years) (Gong et al. 2007). Other population-based studies that disaggregate fatalities by age are scarce, and hence, it is not possible to clearly delineate children's risk relative to other age groups. However, given their increased vulnerability to the disease outbreaks and food shortages that commonly proceed major storm events, it can be reasonably expected that they bear a disproportionate share of the mortality and morbidity burden.

2.4 Heat Waves

While definitions of a heat wave vary, it can generally be defined as "a period of at least 3 days where the combined effect of excess heat and heat stress is unusual with respect to the local climate" (Nairn and Fawcett 2013, p. 13). According to the IPCC, it is very likely that there has been an overall increase in the number of warm days and nights at the global scale, and it is more likely than not that anthropogenic climate change is the cause of this increase (IPCC 2014). Christidis et al. (2012) concluded that it is extremely likely (probability greater than 95 %) that

anthropogenic climate change at least quadrupled the risk of extreme summer heat events in Europe in the decade 1999–2008. In terms of future projections, it is very likely that the length, frequency, and intensity of warm spells or heat waves will increase over most land areas (Smith et al. 2014; IPCC 2013), and by the end of the twenty-first century, a 1-in-20-year annual hottest day is likely to become a 1-in-2-year annual extreme in most regions (IPCC 2013).

Heat waves are a significant threat to human health and they typically increase the overall death rate of a population (Smith et al. 2014). The European heat wave of 2003 caused an estimated 22,000–70,000 deaths, with 14,800 deaths in France alone (IPCC 2007; Kravchenko et al. 2013). While the majority of epidemiological studies find that the elderly have the highest mortality risk, there is emerging evidence that infants and young children are also vulnerable (Xu et al. 2014). Kysely and Kim (2009) found that during the South Korean heat wave of 1994, mortality in children aged 0–14 years increased by 27.5 % which was the largest relative increase of any age group. Hajat et al. (2005) found that during a period of high ambient temperature in Delhi, children younger than 15 years old accounted for 48 % of deaths. According to the 2011 census (Government of National Capital Territory of Delhi 2012), children under 15 account for just 26 % of Delhi's overall population which would suggest that this age group was disproportionately represented in the fatality data.

3 Vector-Borne Diseases

3.1 Malaria

Malaria is among the most widespread diseases in the world (WHO 2014a). In 2013, an estimated 198 million cases of malaria led to 584,000 deaths (WHO 2014a). The burden of disease is heaviest in Africa, where an estimated 90 % of malaria deaths occur, and in children under aged 5 years, who account for 78 % of all deaths globally (WHO 2014a). Children under 5 are highly susceptible to the disease because they have not yet developed the naturally acquired immunity that results from repeated infections (Doolan et al. 2009). For children who survive the disease, neurological and cognitive development can be severely affected. Recent evidence from Uganda suggests that asymptomatic malaria infection is related to lower sustained attention and abstract reasoning abilities (Nankabirwa et al. 2013). Meanwhile, cerebral malaria can lead to acquired language disorders and neurological disorders including epilepsy and cerebral palsy (Idro et al. 2010). Although morbidity and mortality is most concentrated in children under 5, research suggests that infection in school-age children results in increased school absenteeism, repetition of school years, and increased dropout rates (Thuilliez et al. 2010; Zuilkowski and Jukes 2014).

Climate conditions affect the survival and reproductive rates of malarial mosquitoes and also affect the life cycle of the parasitic protozoa responsible for malaria, which in turn influences the distribution, abundance, intensity, and annual temporal

patterns of mosquito activity (particularly biting rates) (Yu et al. 2015; Watts et al. 2015). Holding socioeconomic development constant, Béguin et al. (2011) estimate that predicted increases in temperature and precipitation will result in a geographic expansion of malaria, increasing the global population at risk from 4.61 billion in 2030 to 5.20 billion in 2050. Thus, in regions where climate is currently the limiting factor, there will be a likely increase in the incidence of the disease (Watts et al. 2015; Yu et al. 2015). Expansion into previously non-endemic regions is a major concern because levels of naturally acquired immunity will be much lower than in endemic regions (Béguin et al. 2011; Yu et al. 2015). While research is yet to specifically examine how these changes will affect children, the existing evidence indicates that they will bear a substantial proportion of the disease burden (Doolan et al. 2009).

3.2 Dengue

Dengue is the most rapidly spreading mosquito-borne viral disease in the world (WHO 2015). Over the past 50 years, there has been a 30-fold increase in global incidence, and there has been a significant expansion of the geographic area affected (WHO 2015). While dengue cases are often underreported or misclassified, estimates indicate that dengue transmission is ubiquitous throughout the tropical regions of the Americas and Asia (Bhatt et al. 2013). It is also estimated that risk in Africa, though more unevenly distributed than in other tropical regions, is much more widespread than suggested previously. One global estimate indicates 390 million dengue infections per year, of which 96 million manifest clinically (Bhatt et al. 2013). As with malaria, climate change is expected to drive a geographic expansion of dengue. Hales et al. (2002) estimate that by 2055, population growth alone will increase the population at risk to 3.2 billion people (34 % of the global population), but the additional influence of climate change will increase the population at risk to 4.1 billion people (44 % of the global population).

The dengue virus causes a spectrum of clinical disease ranging from dengue fever – usually characterized by arthralgia, myalgia, and headache – to the more serious dengue hemorrhagic fever (DHF) and dengue shock syndrome (DSS), both of which can be fatal (Bhatt et al. 2013; Hammond et al. 2005). In addition to socioeconomic factors, age is thought to be a major determinant for more serious forms of dengue (Kyle and Harris 2008). Most epidemiologic studies find that children under age 15 are at increased risk for both DHF and DSS which may be due to their increased capillary fragility and decreased tolerance for insult to microvascular integrity (Kyle and Harris 2008). In a 3-year hospital-based study in Nicaragua (Hammond et al. 2005), the incidence of the disease was highest in children aged 5–9 years old (58 % of all cases). Moreover, infants aged 0–11 months and children aged 4–6 years were significantly more likely than adults to develop the more serious clinical manifestations of DHF and DSS. Over the course of the study, children were also more likely to succumb to the disease and accounted for 77 % of the 13 dengue-related deaths. Thus, as climate change drives an increase in the

population at risk of contracting dengue fever, it is likely that children will bear a substantial proportion of the disease burden.

4 Waterborne Diseases

Waterborne diseases caused by viruses, bacteria, and protozoa are spread through contaminated drinking water or recreational water and most commonly result in diarrhea (Schuster-Wallace et al. 2014). Among children under 5, diarrhea continues to be the second most common cause of mortality globally and accounts for at least 11 % of the mortality burden (UNICEF 2012). In 2010 alone, nearly 801,000 children under 5 succumbed to diarrhea, mostly in developing countries (UNICEF 2012). Children under 2 are particularly vulnerable with 72 % of diarrheal deaths occurring within the first 2 years of life (Fischer-Walker et al. 2013). Children are especially vulnerable to diarrheal disease because they must consume more water per body mass than adults, which results in greater exposure to waterborne pathogens (Fischer-Walker et al. 2013; Bennett and Friel 2014). Once exposed, children's immature immune systems are less able to resist infection, while their small body size means that they become dangerously dehydrated very quickly (Bennett and Friel 2014).

The waterborne pathogens that cause diarrheal disease are highly sensitive to meteorological conditions (Moors et al. 2013; Fischer-Walker et al. 2013). There is general consensus that climate change will result in a substantial increase in the incidence of diarrheal disease, and both WHO and the IPCC have identified this as one of the most important future health effects of climate change (WHO 2009a; Smith et al. 2014). Climate projections for assessing the global risk of diarrhea as a result of higher temperatures have estimated an increase of 8–11 % by the 2030s (Kolstad and Johansson 2011). However, other modeling demonstrates that increases are spatially variable. Applying climate projections for Northern India in 2040, Moors et al. (2013) found that increases ranged from no change in the northwest to 13 % in the Ganges River basin to 21 % in the high mountain regions of the Himalayas. In a country where 200,000 children die of diarrhea every year, this represents a major public health concern (Liu et al. 2012).

5 Respiratory Illnesses

Respiratory illnesses, such as pneumonia, are the leading cause of death in children (WHO 2014b; UNICEF 2006). Globally, over two million children die of pneumonia every year, accounting for 20 % of all child deaths (UNICEF 2006). While most healthy children can fight pneumonia infection with their own defenses, children with compromised immune function are at a higher risk of contracting the disease and of succumbing to complications. Children suffering from undernutrition are at a particularly high risk, and 44 % of pneumonia deaths in children are attributed to undernutrition (Paynter et al. 2010, 2013). Susceptibility is also exacerbated by

overcrowded living conditions and indoor air pollution caused by cooking and heating with coal and other biomass fuels, such as wood or dung (WHO 2009a). For this reason, children in developing countries bear a substantial proportion of the global disease burden of pneumonia. For example, in 2011, sub-Saharan Africa accounted for 43 % of all global pneumonia deaths in children aged under 4 years, while Southeast Asia accounted for 35 % (Fischer-Walker et al. 2013). Despite the impacts of pneumonia on child mortality, little attention is given to the disease, and for this reason it is often referred to as the "forgotten killer" (UNICEF 2006).

It is well established that pneumonia follows seasonal patterns – in temperate settings, the incidence increases in the winter months, while in tropical settings, incidence increases during the rainy season (Paynter et al. 2013). In the Gambia, for example, the incidence of clinical pneumonia in children was 409 (per 1000 person years) in the rainy season; 243 in the hot, dry season; and 160 in the cool, dry season (Paynter et al. 2010). While future projections are currently lacking, Paynter et al. (2010) assert that climate change will increase the incidence of childhood pneumonia in tropical settings and propose three mechanisms through which this would occur: (1) more time indoors or undercover because of increased rainfall will increase crowding and exposure to particulate matter from burning coal and biomass; (2) the stability of the virus in aerosols might increase in higher humidity; and (3) undernutrition caused by decreased food security will increase susceptibility to infection. However, all three mechanisms, and their relationship to the incidence of pneumonia in children, are yet to be subjected to empirical scrutiny.

6 Key Uncertainties and Knowledge Gaps

While available evidence indicates that children will be among the worst affected by the health impacts of climate change, there are several knowledge gaps and uncertainties concerning the precise nature of children's exposure and vulnerability (Sheffield and Landrigan 2011). Across the broader literature on the health impacts of climate change, the only study that specifically models impacts on children is Nelson et al.'s (2009) global projection for child undernutrition. A major barrier to projecting future impacts on children is a lack of global and national data on child morbidity and mortality due to climate-sensitive diseases and extreme events (WHO 2009a; Xu et al. 2012). While morbidity and mortality data does exist, it is rarely disaggregated by age, and this is impeding the development of future projections that specifically address child morbidity and mortality under future climate change scenarios.

A major step forward in this domain is the Global Initiative on Children's Environmental Health Indicators (CEHIs), an initiative led by the World Health Organization aimed at improving the assessment of children's environmental health, monitoring the effects of interventions to improve children's health in relation to the environment and reporting on the state of children's environmental health (WHO 2009b). The initiative has three key objectives: (1) develop and promote the use of

children's environmental health indicators; (2) improve the assessment of children's environmental health and monitor the success or failure of interventions; (3) and provide data to inform policymakers and to allow measurement of the effectiveness of policies and programs to improve environmental conditions for children (WHO 2009b). Importantly, the indicators incorporate all of the major health impacts of climate change, including perinatal diseases, respiratory diseases, diarrheal diseases, insect-borne diseases, and physical injuries. However, the extent to which the CEHIs have translated into operational monitoring and surveillance programs is unclear. In most countries there are no good registers of environmentally determined diseases in children, and increased political will and financing are required to ensure this occurs (WHO 2010).

Another issue with the CEHIs is that children are categorized into two main groups of 0–4-year-olds and 5–14-year-olds (Xu et al. 2012). However, these broad categorizations fail to reflect the heterogeneity of children's exposures and vulnerabilities within these groupings. Levels of exposure and vulnerability for a 5-year-old are likely to differ to those for a 14-year-old and likewise for a 1-year-old as compared to a 4-year-old. Thus, there is an ongoing need for research that disaggregates the broad category of "children" at a higher level of precision and increases understanding of the specific health risks that apply to children of different ages. There is also a need to better understand the social determinants of children's exposure and vulnerability to climate-related health risks. While it is clear that poverty and inequality are major determinants of child health and survival (WHO 2009b), there is a need for rigorous research on how individual characteristics such as race, class, gender, and disability influence children's vulnerability to both extreme events and climate-sensitive disease. Such information would help to ensure that resources are allocated to those children who are most at risk. It would also provide an evidence base for addressing the underlying causes of child morbidity and mortality in high-risk groups.

Importantly, this research endeavor will need to provide children with genuine opportunity to actively participate in the process of knowledge and data generation. At present, the bulk of research on children's exposure and vulnerability to the health impacts of climate change is being conducted from the perspectives of adults. As a consequence, children have become what anthropologist Charlotte Hardman (1973) refers to as a "muted group." This dominance of adult voices most likely stems from the long-held assumption that children are unreliable or incompetent informants of their own knowledge and experiences (James and Prout 2004). Over the last decade, however, leading scholars of childhood have concluded that delimiting the emergence of children's own knowledge and experience through the use of adult-centered positivistic methodologies not only creates a false picture of children's experiences but serves to underestimate their competence and agency (Boyden 2003). The adoption of inductive, hermeneutical methodologies that enable children to articulate their experiences from their own perspectives will enhance understanding of the actual and expected impacts of climate change on child health and provide a more rigorous evidence base for the development of policy and programming that meets children's needs.

7 Protecting Child Health and Survival in a Changing Climate

Although current knowledge is characterized by numerous gaps and uncertainties, this must not be seen as a reason to delay action on protecting child health and survival. On the contrary, the potential risks to child health posed by climate change require the application the "precautionary principle" which states that "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (UNCED 1992, Principle 15). Action to protect child health and survival is supported by Article 24 of the *United Nations Convention on the Rights of the Child* which clearly states that children have the right to the enjoyment of the highest attainable standard of health and to facilities for the treatment of illness and rehabilitation of health (United Nations 1989). Also relevant in this context is Article 27 which states that children have the right to a standard of living that is good enough to meet their physical and mental needs (United Nations 1989). In the context of climate change, Pursuing the full implementation of this right requires immediate and drastic actions to both reduce greenhouse gas (GHG) emissions (climate change mitigation) and to assist communities to cope with and adapt to the actual and expected consequences of increasing temperatures (climate change adaptation).

7.1 Climate Change Mitigation

Climate change mitigation refers to efforts to reduce or prevent greenhouse gas (GHG) emissions (Smith et al. 2014). Mitigation can mean using new technologies and renewable energies, making older equipment more energy efficient or changing management practices or consumer behavior (IPCC 2014). Protecting carbon sinks like forests and oceans are also elements of mitigation (IPCC 2014). Substantial emission reductions over the next few decades can reduce climate risks in the twenty-first century and beyond, increase prospects for effective adaptation, reduce the costs and challenges of mitigation in the longer term, and contribute to climate-resilient pathways for sustainable development (IPCC 2014). The IPCC states with high confidence that without additional efforts to reduce GHG emissions beyond those in place today, population growth and economic activities will lead to an increase in global mean surface temperature of up to 4.8 °C in 2100 (IPCC 2014). The risks associated with temperatures at or above 4 °C include substantial species extinction, global and regional food insecurity, consequential constraints on common human activities and potentially catastrophic effects on human health in both developing and developed nations (IPCC 2014; WHO 2009a; Watts et al. 2015).

Among the scientific community, there is general agreement that the catastrophic impacts of climate change can be avoided if the global temperature rise is kept to no more than 2 °C above preindustrial levels (IPCC 2014; Watts et al. 2015). This will require substantial emission reductions over the next few decades and near-zero

emissions of greenhouse gases by the end of the century (IPCC 2014). Implementing such reductions poses substantial technological, economic, social, and institutional challenges at both national and international levels and involves some level of risks due to adverse side effects (i.e., devaluing of fossil fuel assets and reduced revenues for fossil fuel exporters) (IPCC 2014). However, these risks do not involve the same possibility of severe, widespread, and irreversible impacts as risks from climate change (IPCC 2014). In addition to preventing catastrophic climate change, reducing greenhouse gas emissions will have major "co-benefits" across different sectors, including public health (IPCC 2014; Watts et al. 2015; WHO 2009a). The public health co-benefits of mitigation exist across five main categories, all of which have particular relevance to protecting child health:

- *Household energy*. In developing countries, enabling households to move from inefficient burning of coal and biomass fuels for domestic use to cleaner sources of energy would significantly reduce greenhouse gas emissions and would also reduce the estimated two million annual deaths from indoor air pollution (WHO 2009a).
- *Electricity generation*. A shift toward renewable energy sources for electricity generation would cut greenhouse gas emissions as well as reduce the current 1.2 million annual deaths from outdoor urban air pollution (WHO 2009a).
- *Urban transport systems*. Promotion of safe and sustainable public transport systems would dramatically cut carbon emissions and would also help to reduce the 3.2 million annual deaths from noncommunicable diseases associated with physical inactivity. It would help to reduce the 1.3 million annual deaths from road traffic accidents (WHO 2009a). A chapter in this volume by Paul Tranter and Scott Sharpe reflects in more detail on this issue and its relevance to children.
- *Food and agriculture*. The food and agriculture sector contributes about 10–12 % of global greenhouse gas emissions, with additional contributions from associated land-use change (e.g., deforestation) (Watts et al. 2015; IPCC 2014). Moderating meat consumption and increasing intake of foods that are lower on the food chain has the potential both to enhance health and reduce greenhouse gas emissions (Smith et al. 2014; WHO 2009a).

Taken together, these health co-benefits have the potential to offset a large part of the financial cost of GHG emission reduction policies (WHO 2009a). Several cost-benefit analyses show that shifts to a low-carbon economy are paid for by subsequent improvements in public health. In a cost-benefit analysis of the United States Clean Air Act, every dollar invested in implementation generated 42 dollars in societal gains, a large proportion of which was gained through health benefits (EPA 2011). The 2007 IPCC report also showed that the costs of many climate change mitigation interventions would be partly or wholly compensated for by the associated health benefits (IPCC 2007). While this point is rarely raised in debates about the economics of climate change mitigation, it offers a way of securing a broad and inclusive platform of public and political support for action (Bennett and Friel 2014; Watts et al. 2015). As such, the health community should play a more active role in the

design of greenhouse gas mitigation policies: failure to select the most health-enhancing actions for mitigation would be a lost opportunity for present and future generation and would reduce the return on investment in low-carbon and renewable energy sources (WHO 2009a; Watts et al. 2015).

Another way of securing support for climate change mitigation is by representing it in ways that anchor it in positive emotions and by framing it in ways that connect with people's core values and identities (Watts et al. 2015; Markowitz and Shariff 2012). A leading example involves framing climate change as an issue of intergenerational justice (Gibbons 2014; see also Davies et al. in this volume). The principle of intergenerational justice argues that there should be distributive justice between generations and that the rights of generations should be considered equal over time (Stone and Lofts 2009). Gibbons (2014) has argued that children alive today and those not yet born have a claim to climate justice, both within their own countries and internationally. This claim is currently being tested in a range of countries, where lawyers are working with children and youth to advance of a variety of science-based legal actions to compel government action on climate change (Children's Climate Trust 2015). While the outcomes of these cases are still pending, they have done much to increase public discussions of intergenerational justice and the moral rights of children and youth in present and future generations.

Principles of intergenerational justice have also been used to increase child representation and participation in global negotiations on climate mitigation. Intergenerational justice requires that agreements for mitigation ensure not only that the rights of future generations are fulfilled but also that the decision-making process includes the views of children (Walden et al. 2009). Importantly, children's right to be heard in global climate negotiations is upheld by Article 12 of the United Nations Convention on the Rights of the Child which clearly states that children have a right to participate in decision-making that affects them (UN 1989). In the lead up to the United Nations Framework Convention on Climate Change (UNFCC) 15th Conference of the Parties (COP15) in 2010, international child-rights advocates called on decision-makers to acknowledge children as official stakeholders, provide formal mechanisms for children and youth to participate in formal negotiation processes, and contribute to decision-making on climate change (Walden et al. 2009).

In response to this call, the UNFCCC secretariat granted a provisional constituency status to youth aged between 15 and 24 years old (UNFCCC 2012). As reported by the UNFCCC (2012), this constituency, referred to as YOUNGO (Youth Non-Governmental Organizations), has provided a conduit for the exchange of official information between young people and the secretariat; assisted the secretariat in ensuring effective participation by youth appropriate to an intergovernmental meeting; coordinated young people's interaction at sessions including convening constituency meetings and organizing meetings with officials; and provided logistical support to youth during sessions (UNFCCC 2012). In practical terms, YOUNGO is given the opportunity to address the plenary, high-level segment of a COP, make submissions (individual youth organizations can also do so), attend workshops, and

meet with officials of the convention such as chairs of the subsidiary bodies and the COP Presidency (UNFCCC 2012). However, academic literature on the adequacy or efficacy of these processes is lacking. To date, no published studies critically evaluate children's experiences of participating in these processes or the extent to which children's views have informed actions and outcomes. It is also worth noting that the YOUNGO constituency is for 15–24-year-olds, and, hence, there is no formal mechanism for the participation of younger children. In this respect, fulfilling Article 12 of the UNCRC is an ongoing project.

7.2 Climate Change Adaptation

In parallel to mitigation, adaptation is regarded as an integral part of climate policy (IPCC 2014). The emphasis on adaptation is partially due to the time lag between current emissions and the projection of increased greenhouse gas concentrations in the atmosphere (IPCC 2014). Even if greenhouse gas emissions were to halt immediately, temperatures would be expected to rise by over 0.6 °C in this century (WHO 2009a). If the world was to place a high priority on shifting to sustainable and renewable energy over the next several decades, temperatures are still expected to rise by 1.8 °C (likely range: 1.1–2.9 °C) (WHO 2009a). There is scientific consensus that even a 2 °C rise will result in insecurity for millions of people in terms of food, water, and shelter, with all of the attendant risks for child health (Smith et al. 2014). Thus, strategies that facilitate adaptation and build resilience are required. In the climate change literature, adaptation refers to "the process of adjustment to actual or expected climate and its effects, in human systems in order to moderate harm or exploit beneficial opportunities, and in natural systems human intervention may facilitate adjustment to expected climate change" (Watts et al. 2015, p. 15). Resilience, meanwhile, refers to "the capacity of a system to absorb disturbance and reorganise while undergoing change, so as to still retain essentially the same function, structure, identity and feedbacks" (Watts et al. 2015, p. 15).

Over the last decade, adaptation and resilience have received substantial attention in both policy and research, and more recently adaptation and resilience for human health have emerged as a focal point in the adaptation discourse (Bowen and Friel 2012; Watts et al. 2015). However, despite their well-documented vulnerability to the health impacts of climate change, children have not featured prominently in such literature (Xu et al. 2012). Yet, adaptations to climate change will be less than adequate if they fail to take account the particular vulnerabilities of children, the protective factors that can best support their resilience and their capacities to contribute to adaptation (Mitchell and Borchard 2014).

As several authors point out, there are strong synergies between what children need to thrive and become healthy adults and the adaptations that are required to reduce the health risks of climate change (Bennett and Friel 2014). The social and economic determinants of child mortality and morbidity are well known and include poverty, hunger, and lack of access to clean water and sanitation (WHO 2009a; Sheffield and Landrigan 2011). Over the last 15 years, since the inception of the

Millennium Development Goals (MDGs), major progress has been made across these areas: the number of people living in extreme poverty has been halved; the number of undernourished people has fallen from 23.3 % to 12.9 %; the number of people using an improved drinking water source has increased from 76 % to 91 %; and the number of people practicing open defecation has been reduced significantly (UN 2015). However, as highlighted in the final report for the MDGs, progress has been uneven, and in developing regions significant inequities exist between the poorest and richest households and between rural and urban areas (UN 2015). While protecting child health will require a significant reduction in these inequities, climate change is expected to exacerbate them even further (Bennett and Friel 2014).

Climate change will strain health systems of those countries that already face the public health challenges of poor health infrastructure, poverty, and inequality (Watts et al. 2015). Populations that do not have access to good quality health care and essential public health services are more likely to be adversely affected by climate variability and climate change (Frumkin and McMichael 2008). Therefore, strengthening of public health systems needs to be a central component of adaptation to climate change (Watts et al. 2015; WHO 2009a; Smith et al. 2014). In regions where the health impacts of climate change are expected to be most severe, broadening the coverage of available health programs and interventions would greatly improve current child health status and, combined with forward planning, would increase adaptive capacity for dealing with future challenges (WHO 2009a). This will require significant investment, particularly in developing countries. Watts et al. (2015) argue that donor countries have a responsibility to support measures which reduce the impacts of climate change on human health and build adaptive capacity. Given the increased vulnerability of children, beneficiary countries also have a responsibility to prioritize investment in health services that address the current and future health-care needs of this group (WHO 2009a).

Many of the most important adaptive actions for protecting child health are public health interventions of proven effectiveness. For example, malaria interventions are highly effective and affordable (WHO 2009a). The main interventions comprise vector control (which reduces transmission by the mosquito vector from humans to mosquitoes and then back to humans), achieved using insecticide-treated mosquito nets (ITNs) or indoor residual spraying (IRS); chemoprevention (which prevents the blood stage infections in humans); and case management (which includes diagnosis and treatment of infections) (WHO 2009a). In sub-Saharan Africa, ITNs are estimated to reduce malaria mortality rates by 55 % in children under 5 years of age (WHO 2014a). Their public health impact is due to a reduction in malaria deaths and to reductions in child deaths from other causes that are associated with, or exacerbated by, malaria (e.g., acute respiratory infection, low birth weight, and malnutrition) (WHO 2009a). Chemoprevention is particularly effective in pregnant women and young children, and WHO (2009a) estimates that seasonal malaria chemoprevention for children aged 3–59 months could avert millions of cases and thousands of deaths in children living in areas of highly seasonal malaria transmission in Africa's Sahel subregion.

Climate change adaptation also requires strengthening health systems to deal with the predicted increases in the intensity and frequency of extreme weather events. Acute shocks such as natural disasters and disease epidemics can overload the capacities of health systems in even the most developed nations (WHO 2009a). There is an urgent need to increase the capacity of health systems to ensure that people are better protected from the increasing hazards of extreme weather events (WHO 2009a). Approaches to the health management of extreme weather events involve improving forecasting and early warning systems, predicting possible health outcomes, contingency planning, and identifying the most vulnerable (i.e., children) (Watts et al. 2015). Despite their well-documented vulnerabilities to extreme events and the associated health impacts, children are often overlooked in disaster risk management policies and plans. The US National Commission on Children and Disasters (2010) found that very few states had school evacuation and family reunification plans, and only 6 % of hospital emergency departments had supplies and equipment to treat children. In Australia, a recent analysis of local government emergency management plans found that the needs of pets and livestock were mentioned more regularly than the needs of children (Save the Children 2013).

Access to education also has a major role to play in building adaptive capacities. Toya and Skidmore (2007) found a significant role for education in reducing vulnerability to hazard impacts, and Watts et al. (2015) assert that education levels are important in the ability of societies to cope with extreme events. Educating girls appears to be particularly beneficial, and there is some evidence that education levels of women are a critical factor in reducing household vulnerability to death and injury in weather-related disasters (Toya and Skidmore 2007). This evidence is consistent with an extensive literature documenting the effects of female education on community-level social capital and health-related indices, such as life expectancy (King and Mason 2001). As Blankespoor et al. (2010) note, educating young women and girls is also one of the major determinants, if not *the* major determinant, of sustainable development. Curricula that provide the requisite knowledge and skills for effective adaptation are also essential (Anderson 2010). While progress is being made in this domain (e.g., Selby and Kagawa 2013; Kagawa and Selby 2010), the work remains ad hoc, and climate change education is rarely identified as a key priority in national or local adaptation plans. If present and future generations are to find effective and sustainable solutions for adaptation, a more systematic approach to climate change education is required (Kagawa and Selby 2010; Selby and Kagawa 2014).

The fundamental importance of climate change education is highlighted in the rapidly expanding literature on community-based climate change adaptation which emphasizes the fundamental importance of public participation in the design and implementation of adaptation activities at the local level (Reid et al. 2009). A burgeoning literature demonstrates that for solutions to be effective and sustainable, they must be informed by the knowledge and experience of local people (Schipper et al. 2014). There is also growing evidence that children's participation in local adaptation activities not only protects child health and survival but provides benefits to entire communities (Mitchell and Borchard 2014; Tanner et al. 2009;

Tanner 2010; Mitchell et al. 2008). Mitchell and Borchard (2014) cite several compelling anecdotal examples, including one from Kenya, where school children have learned about the impacts of climate change on water and food security and have grown vegetables in "gunny sacks" (large bags used to transport grain), which uses less water than traditional methods; they have also experimented with drought-tolerant crops and shared the results with transitioning pastoralists.

A growing body of academic research has emphasized children's capacities for participating in climate change adaptation (Tanner 2010; Tanner et al. 2009; Mitchell et al. 2008). This research has contributed to a fundamental "shift in the narrative," from children as passive victims of climate change to children as active agents of change (Tanner 2010). Drawing on a suite of participatory action research (PAR) projects in the Philippines and El Salvador, Tanner et al. (2009) identify five core domains in which children can participate in climate change adaptation:

- Assessing risk and risk reduction activities
- Designing and implementing projects
- Communicating risks and risk management options to their households and communities
- Mobilizing resources and people
- Constructing social networks and social capital

A more recent study by Haynes and Tanner (2013), conducted in the Philippines, provides further evidence of children's capacities for participating across these core domains. Utilizing participatory video (PV) methods, this study involved children and youth (13–18 years old) in identifying local climate risks, researching the underlying social and political risk drivers, producing short films to communicate their findings to local decision-makers and community members, and participating in follow-up workshops to develop community-based strategies for adaptation. Through the PV process, one particular group of children discovered that chromite mining was exacerbating the health impacts of extreme rainfall events and flooding in their village. Not only was chromite mining contaminating flood waters and causing skin disease, but water-filled mining pits were providing breeding grounds for mosquitoes and increasing the risk of malaria. Their film revealed that chromite mining was a divisive issue in the community between those who were benefiting from the mining and those who were exposed to the risks but received no benefits. Following a local screening of the film, the children organized a community meeting to openly discuss the various issues, and as a result local officials banned mining close to the village and pledged to rehabilitate old mining pits. In a region where climate change is expected to increase the frequency and intensity of extreme rainfall events, preventing the contamination of flood waters and eradicating mosquito breeding sites is an essential adaptation measure.

While the available evidence provides support for child participation in climate change adaptation, there is an urgent need for increased research outputs. As Mitchell and Borchard (2014) point out, there is no solid evidence base proving that what has worked in a growing number of cases is more broadly applicable,

translatable to other regions, or sustainable in the absence of direct project support. There is also a distinct need for research that focuses on younger children. To date, the majority of published studies involve older children and youth aged between 11 and 18. Yet, it would appear that it is younger children and infants who are most vulnerable to both extreme events and climate-sensitive disease. While the participation of infants will obviously be constrained by their still developing cognitive and communication abilities, it is generally agreed that school-age children are capable of engaging in the research process, so long as child-friendly research methods are employed (Eder and Fingerson 2002).

8 Conclusion

This chapter has reviewed the available literature on the health impacts of climate change on children and the various pathways toward protecting child health and survival. There is a general scientific consensus that climate change will cause an increase in the frequency and intensity of extreme weather events (i.e., heat wave, flood, drought, tropical cyclone) and exacerbate the spread of climate-sensitive diseases (i.e., malaria, dengue, pneumonia, diarrhea). It is also widely understood that climate change will lead to an increase in mortality and morbidity, particularly in developing countries where exposure is highest and vulnerability is most entrenched. While the available evidence indicates that children will be most severely impacted, a lack of data on child mortality and morbidity is impeding the development of mathematical models for reliable estimates under various climate change scenarios. Of particular importance is the need to disaggregate data at a level of precision that can account for physical, behavioral, and social heterogeneity of childhood. Where child health data is being collected, it is most commonly grouped into 0–4-year-olds and 5–14-year-olds. These categories are insufficiently fine-grained for fully understanding the distinct exposures and vulnerabilities at different stages of child development. There is also a need to better understand children's environmental health from their own perspectives, especially with regard to how their daily activities and routines influence their exposure and vulnerability.

However, the lack of definitive estimates of impacts for the various stages of childhood should not delay action on climate change mitigation and adaptation to protect child health and survival. Rather, the potential risks to child health and associated consequences for the acquisition of human capital would seem to require the application of the "precautionary principle." Importantly, many climate change mitigation measures have major co-benefits for public health in general and child health, in particular. Framing mitigation policy in terms of health co-benefits and as an issue of intergenerational justice is more likely to secure public support for the kind of drastic actions that are needed to avoid catastrophic climate change. Principles of intergenerational justice also require that children and young people are provided with opportunities for genuine participation in the development of climate policy. While recent efforts have ensured that there are formal mechanisms for youth to participate in international climate change negotiations, children under the age of

15 have not been afforded the same opportunities. Yet, they are the ones who are most vulnerable to the health impacts of extreme events and climate-sensitive disease and thereby have the strongest claim to climate justice. Upholding children's rights to participate in decision-making that affects them requires the implementation of formal mechanisms for the participation of younger children as well youth.

Children must also be provided with increased opportunities to participate in climate change adaptation. While it is often assumed that children are helpless victims of extreme events and disease, it is increasingly recognized that they have an essential role to play in adaptation research, policy, and practice. Historically, children's exposure and vulnerability to extreme events and climate-sensitive disease have been studied from the perspectives of adults, and children's needs and capacities have not been ranked as a high priority in adaptation planning. However, it is becoming increasingly clear that when children have an opportunity to participate in knowledge generation and the development of adaptation solutions, the entire community benefits. Yet, child-centered adaptation research remains very much a niche topic in the wider adaptation literature. If current and future generations of children are to be protected from the health impacts of climate change, the climate change community will need to make a more concerted effort to incorporate the needs and capacities of children into its core agenda. Not only will this provide a stronger basis for solutions that are sensitive to the realities of children's everyday lives, it will also ensure that broader measures for mitigation and adaptation do not impact adversely on their health and survival.

References

Alderman, K., Turnera, L., & Tonga, S. (2012). Floods and human health: A systematic review. *Environment International, 47*, 37–47.

Anderson, A. (2010). *Combating climate change through quality education*. Washington, DC: The Brookings Institution. Available at.

Béguin, A., Hales, S., Rocklöv, J., Åström, C., Louis, V., & Sauerborn, R. (2011). The opposing effects of climate change and socio-economic development on the global distribution of malaria. *Global Environmental Change, 21*, 1209–1214.

Bennett, C., & Friel, S. (2014). Impacts of climate change on inequities in child health. *Children, 1*, 461–473.

Bhatt, S., Gething, P., Brady, O., et al. (2013). The global distribution and burden of dengue. *Nature, 496*, 504–507.

Black, R., Victora, C., Walker, S., Bhutta, Z., Christian, P., de Onis, M., Ezzati, M., Grantham-McGregor, S., Katz, J., Martorell, R., & Uauy, R. (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries. *The Lancet, 382*, 427–451.

Blankespoor, B., Dasgupta, S., Laplante, B., & Wheeler, D. (2010). *Adaptation to climate extremes in developing countries: The role of education*. Washington, DC: World Bank. Working paper by the World Bank Development Research Group Environment and Energy Team.

Bowen, K., & Friel, S. (2012). Climate change adaptation: Where does global health fit in the agenda? *Globalization and Health, 8*, 1–7.

Boyden, J. (2003). Children under fire: Challenging assumptions about children's resilience. *Children, Youth and Environments, 13*(1), 1–21.

Children's Climate Trust. (2015). *Securing the legal right to a healthy atmosphere and stable climate for all present and future generations.* Available at http://ourchildrenstrust.org/.

Chowdury, A., Bhuyia, A., Choudury, A., & Sen, R. (1993). The Bangladesh cyclone of 1991: Why so many people died. *Disasters, 17*, 291–304.

Christidis, N., Stott, P. A., Jones, G. S., Shiogama, H., Nozawa, T., & Luterbacher, J. (2012). Human activity and anomalously warm seasons in Europe. *International Journal of Climatology, 32*, 225–239.

CRED. (2015). *The international disaster database.* Centre for Research on the Epidemiology of Disasters. Available at http://www.emdat.be/.

Dasgupta, S., Laplante, B., Murray, S., & Wheeler, D. (2009). *Climate change and the future impacts of storm-surge disasters in developing countries* (Working Paper 182). Washington, DC: Center for Global Development (CDG).

Doocy, S., Daniels, A., Murray, S., & Kirsch, T. D. (2013). The human impact of floods: A historical review of events 1980–2009 and systematic literature review. *PLOS Current Disasters*. doi:10.1371/currents.dis.f4deb457904936b07c09daa98ee8171a. Apr 16, Edition 1.

Doolan, D., Doban, C., & Baird, J. (2009). Acquired immunity to malaria. *Clinical Microbiology Reviews, 22*, 13–36.

Eder, D., & Fingerson, L. (2002). Interviewing children and adolescents. In J. F. Gubrium & J. A. Holstein (Eds.), *Handbook of interview research: Context and method* (pp. 181–201). Thousand Oaks: Sage.

EPA. (2011). *The benefits and costs of the clean air Act from 1990 to 2020.* U.S. Environmental Protection Agency Office of Air and Radiation, Washington, DC. Available at http://www2.epa.gov/sites/production/files/2015-07/documents/summaryreport.pdf.

Fischer-Walker, K., Rudan, K., Liu, L., Nair, H., Theodoratou, E., Bhutta, Z., O'Brien, K., Campbell, H., & Black, R. (2013). Global burden of childhood pneumonia and diarrhea. *Lancet, 381*, 1405–1416.

Frumkin, H., & McMichael, A. J. (2008). Climate change and public health: Thinking, communicating, acting. *American Journal of Preventive Medicine, 35*(5), 403–410.

Gibbons, E. (2014). Climate change, children's rights, and the pursuit of intergenerational climate justice. *Health and Human Rights Journal, 214*, 19–31.

Gong, Z., Chai, C., Tu, C., Lin, J., Gao, Y., & Qiu, Y. (2007). Injuries after a Typhoon in China. *New England Journal of Medicine, 356*, 196–197.

Government of National Capital Territory of Delhi. (2012). *Statistical abstract of Delhi 2012*. Delhi: Directorate of Economics & Statistics. Available at http://delhi.gov.in/DoIT/DES/Publication/abstract/SA2012.pdf.

Grantham-McGregor, S., Cheung, Y. B., Cueto, S., et al. (2007). Developmental potential in the first 5 years for children in developing countries. *Lancet, 369*, 60–70.

Hajat, S., Armstrong, B., Gouveia, N., & Wilkinson, P. (2005). Mortality displacement of heat-related deaths: A comparison of Delhi, Sao Paulo, and London. *Epidemiology, 16*, 613–620.

Hales, S., De Wet, N., Maindonald, J., et al. (2002). Potential effect of population and climate changes on global distribution of dengue fever: An empirical model. *The Lancet, 360*, 830–834.

Hammond, S., Balmaseda, A., & Pérez, L. (2005). Differences in dengue severity in infants, children, and adults in a 3-year hospital-based study in Nicaragua. *American Journal Tropical Medicine and Hygiene, 73*, 1063–1070.

Hardman, C. (1973). Can there be an anthropology of children? *Journal of the Anthropological Society Oxford, 4*(1), 85–99.

Haynes, K., & Tanner, T. (2013). Empowering young people and strengthening resilience: youth-centred participatory video as a tool for climate change adaptation and disaster risk reduction. *Children's Geographies, 13*(3), 357–371.

Idro, R., Kakooza-Mwesige, A., Balyejjussa, S., Mirembe, G., Mugasha, C., Tugumisirize, J., & Byarugaba, J. (2010). Severe neurological sequelae and behaviour problems after cerebral malaria in Ugandan children. *BMC Research Notes, 3*, 104–111.

IPCC. (2007). In S. Soloman, M. Qin, Z. Manning, M. Chen, K. Marquis, M. Averyt, & H. Miller (Eds.), *Climate change 2007: The physical science basis. Contribution of Working Group I to the 4th Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.

IPCC. (2012). In C. B. Field, V. Barros, T. F. Stocker, D. Qin, D. J. Dokken, K. L. Ebi, M. D. Mastrandrea, K. J. Mach, G.-K. Plattner, S. K. Allen, M. Tignor, & P. M. Midgley (Eds.), *Managing the risks of extreme events and disasters to advance climate change adaptation. A special report of Working Groups I and II of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.

IPCC. (2013). In T. Stocker, G. Qin, M. PLattner, S. Tignor, J. Allen, A. Boschung, Y. Nauels, V. Xia, & P. Midgley (Eds.), *Climate change 2013: The physical science basis. Contribution of Working Group I to the 5th Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.

IPCC. (2014). In Core Writing Team, R. K. Pachauri, & L. A. Meyer (Eds.), *Climate change 2014: Synthesis report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva: IPCC.

James, A., & Prout, A. (2004). *Constructing and reconstructing childhood*. New York: Palgrave Macmillan.

Kagawa, F., & Selby, D. (Eds.). (2010). *Education and climate change: Living and learning in interesting times*. New York: Routledge. 276pp.

Kolstad, E., & Johansson, K. (2011). Uncertainties associated with quantifying climate change impacts on human health: A case study for diarrhea. *Environmental Health Perspectives, 119*, 299–305.

Kravchenko, J., Abernethy, A., Fawzy, M., & Lyerly, K. (2013). Minimization of heatwave morbidity and mortality. *American Journal of Preventative Medicine, 44*, 274–282.

Kyle, J., & Harris, E. (2008). Global spread and persistence of dengue. *Annual Review of Microbiology, 62*, 71–92.

Kysely, J., & Kim, J. (2009). Mortality during heat waves in South Korea, 1991 to 2005: How exceptional was the 1994 heat wave? *Climate Research, 38*, 105–116.

Liu, L., Johnson, H. L., Cousens, S., Perin, J., Scott, S., Lawn, J. E., et al. (2012). Global, regional, and national causes of child mortality: An updated systematic analysis for 2010 with time trends since 2000. *Lancet, 379*, 2151–2161.

Lloyd, S. J., Kovats, R. S., & Chalabi, Z. (2011). Climate change, crop yields, and undernutrition: Development of a model to quantify the impact of climate scenarios on child undernutrition. *Environmental Health Perspectives, 119*, 1817–1823.

Markowitz, E., & Shariff, A. (2012). Climate change and moral judgement. *Nature Climate Change, 2*, 243–247.

Mason, A. & King, E. (2001). *Engendering development through gender equality in rights, resources, and voice*. World Bank: Washington, DC.

Mitchell, P., & Borchard, C. (2014). Mainstreaming children's vulnerabilities and capacities into community-based adaptation to enhance impact. *Climate and Development, 6*, 372–381.

Mitchell, T., Haynes, K., Hall, N., Choong, W., & Oven, K. (2008). The role of children and youth in communicating disaster risk. *Children, Youth and Environments, 20*(10), 1–30.

Moors, E., Singh, T., Siderius, C., Balakrishnan, S., & Mishra, A. (2013). Climate change and waterborne diarrhoea in northern India: Impacts and adaptation strategies. *Science of the Total Environment, 468–469*(Suppl), S139–S151.

Nairn, J. & Fawcett, R. (2013). *Defining heatwaves: Heatwave defined as a heat- impact event servicing all community and business sectors in Australia.* CSIRO/Bureau of Meterology, South Australia.

Nankabirwa, J., Wandera, B., Kiwanuka, N., Staedke, S., Kamya, M., & Brooker, S. (2013). Asymptomatic plasmodium infection and cognition among primary schoolchildren in a high malaria transmission setting in Uganda. *American Journal of Tropical Medicine and Hygiene, 88*, 1102–1108.

National Commission on Children and Disasters. (2010). *Report to the President and Congress.* Available at http://archive.ahrq.gov/prep/nccdreport/index.html. Accessed 13 Oct 2015.

Nelson, G., Rosegrant, M., Koo, J., Robertson, R., Sulser, T., Zhu, T., Ringler, C., Msangi, S., Palazzo, A., Batka, M., Magalhaes, M., Valmonte-Santos, R., Ewing, M., & Lee, D. (2009). *Climate change: Impacts on agriculture and costs of adaptation*. Washington, DC: International Food Policy Research Institute.

Paynter, S., Ware, R., Weinstein, P., Williams, G., & Sly, P. (2010). Childhood pneumonia: A neglected climate-sensitive disease. *Lancet, 376*, 1804–1805.

Paynter, S., Weinstein, P., Ware, R., Lucero, M., Tallo, V., Nohynek, H., Barnett, A., Skelly, C., Simoes, E., Sly, P., & Williams, G. (2013). Sunshine, rainfall, humidity and child pneumonia in the tropics: Time-series analysis. *Epidemiology Infection, 141*, 1328–1336.

Pradhan, E., West, K., Katz, J., LeClerc, S., Khatry, S., & Shrestha, S. (2007). Risk of flood related mortality in Nepal. *Disasters, 31*, 57–70.

Reid, H., Cannon, T., Berger, R., Alam, M., & Milligan, A. (Eds.). (2009). *Participatory learning and action community-based adaptation to climate change*. London: IIED.

Save the Children. (2013). *Don't leave me alone: Protecting children in Australian disasters and emergencies – Government report card on emergency management planning*. East Melbourne: Save the Children. Available at https://www.savethechildren.org.au/__data/assets/pdf_file/0019/7921/301013_Dont_Leave_Me_Alone.pdf.

Schipper, L., Ayers, J., Reid, H., Huq, S., & Rahman, A. (Eds.). (2014). *Community-based adaptation to climate change: Scaling it up*. London: Routledge.

Schuster-Wallace, C., Dickin, S., & Metcalfe, C. (2014). Waterborne and foodborne diseases, climate change impacts on health. In B. Freedman (Ed.), *Handbook of global environmental pollution* (pp. 616–622). London: Springer.

Selby, S., & Kagawa, F. (2013). *Climate change in the classroom: UNESCO course for secondary teachers on climate change education for sustainable development*. Paris: UNESCO. http://www.unesco.org/new/ccesd.

Selby, D., & Kagawa, F. (2014). *Towards a learning culture of safety and resilience: Technical guidance for integrating disaster risk reduction in the school curriculum*. Paris: UNESCO. UNICEF: Geneva http://unesdoc.unesco.org/images/0022/002293/229336e.pdf.

Sheffield, P., & Landrigan, P. (2011). Global climate change and children's health: Threats and strategies for prevention. *Environmental Health Perspectives, 119*, 291–298.

Smith, K. R., Woodward, A., Campbell-Lendrum, D., Chadee, D. D., Honda, Y., Liu, Q., Olwoch, J. M., Revich, B., & Sauerborn, R. (2014). Human health: Impacts, adaptation, and co-benefits. In C. B. Field (Ed.), *Climate change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 709–754). Cambridge, UK: Cambridge University Press.

Stanke, C., Kerac, M., Prudhomme, C., Medlock, J., & Murray, V. (2013). Health effects of drought: A systematic review of the evidence. *PLOS Current Disasters*. doi:10.1371/currents.dis.7a2cee9e980f91ad7697b570bcc4b0041. June 5, Edition 1.

Stone, L. & Lofts, K. (2009). Climate change, child rights and intergenerational justice. *IDS In Focus Policy Briefing,* 13. https://www.ids.ac.uk/files/dmfile/IF13.2.pdf.

Tanner, T. (2010). Shifting the narrative: Child-led responses to climate change and disasters in El Salvador and the Philippines. *Children & Society, 24*, 339–351.

Tanner, T., Garcia, M., Lazcano, J., Molina, F., Molina, G., Rodriguez, G., Tribunalo, B., & Seballos, F. (2009). Children's participation in community-based disaster risk reduction and adaptation to climate change. *IEED Participatory Learning Action Plans, 60*, 54–64.

Thuilliez, J., Sissoko, M., Toure, O., Kamate, P., Berthelemy, J., & Doumbo, O. (2010). Malaria and primary education in Mali: A longitudinal study in the village of Doneguebougou. *Social Science Medicine, 71*, 324–334.

Toya, H., & Skidmore, M. (2007). Economic development and the impacts of natural disasters. *Economics Letters, 94*(1), 20–25.

UN. (1989). *Convention on the rights of the child.* Available at http://www2.ohchr.org/english/law/crc.htm.

UN. (2015). *The millennium development goals report 2015*. New York: United Nations.

UNCED. (1992). *Report of the United Nations Conference on Environment and development. Annex 1: Rio Declaration on Environment and Development*. New York: United Nations. Available at http://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm.

UNFCCC. (2012). *Youth participation in the UNFCCC negotiation process: The United Nations, young people, and climate change.* Available at https://unfccc.int/files/conference_programme/application/pdf/unfccc_youthparticipation.pdf.

UNICEF. (2006). *Pneumonia: The forgotten killer of children*. Geneva: UNICEF/WHO.

UNICEF. (2012). *Pneumonia and diarrhea: Tackling the deadliest diseases for the world's poorest children*. Geneva: UNICEF. Available at http://www.unicef.org/eapro/Pneumonia_and_Diarrhoea_Report_2012.pdf.

Walden, N., Hall, N., & Hawrylyshyn, K. (2009). *Global warning: Children's right to be heard in global climate change negotiations*. London: Plan International.

Watts, N., Adger, N., Agnolucci, P., et al. (2015). Health and climate change: Policy responses to protect public health. *The Lancet, 386*, 1861–1914.

WHO. (2009a). *Protecting health from climate change*. Geneva: WHO.

WHO. (2009b). *Children's environmental health indicators (CEHI): Presenting regional successes learning for the future*. Geneva: WHO.

WHO. (2010). *World Health Organization children's health and the environment annual report – 2010*. Geneva: WHO.

WHO. (2014a). *World malaria report*. Geneva: WHO.

WHO. (2014b). *Pneumonia. Fact sheet No.331.* Available at http://www.who.int/mediacentre/factsheets/fs331/en/.

WHO. (2015). *Dengue and severe dengue. Fact sheet N° 117*. Geneva: WHO. Available at http://www.who.int/mediacentre/factsheets/fs117/en/.

Xu, Z., Sheffield, P., Hu, W., Hong, Su., Yu, W., Qi, X., & Tong, S. (2012). Climate change and children's health—a call for research on what works to protect children. *International Journal of Environmental Research and Public Health, 9*, 3298–3316.

Xu, Z., Sheffield, P., Su, H., Wang, X., Bi, Y., & Tong, S. (2014). The impact of heat waves on children's health: A systematic review. *International Journal Biometeorology, 58*, 239–247.

Yu, W., Mengersenb, K., Dalec, P., Yea, X., Guoa, Y., Turnera, L., Wanga, X., Biad, Y., McBrideе, W., Mackenzief, J., & Tonga, S. (2015). Projecting future transmission of malaria under climate change scenarios: Challenges and research needs. *Critical Reviews in Environmental Science and Technology, 45*, 777–811.

Zuilkowski, S., & Jukes, M. (2014). Early childhood malaria prevention and children's patterns of school leaving in the Gambia. *British Journal of Educational Psychology, 84*, 483–501.