15 Lessons learned and insights for adaptation policy

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1. INTRODUCTION

The preface of this book laid out two lines of questioning to be addressed in the case studies:

- What modifications to public health systems might be necessary to enhance adaptive capacity to climate variability and change?
- What lessons can be drawn from the history of managing environmental and other threats that can be applied to adaptation to climate variability and change?

We return to these themes in this concluding chapter, summarizing lessons learned from the case studies that may be applicable to all sectors – including public health – likely to be affected by climate change, then suggesting new directions to take climate variability and change more fully into account when formulating strategies, policies, and measures.

2. NEW CHALLENGES POSED BY CLIMATE CHANGE

Climate change is one of an emerging class of environmental problems that are markedly complex for both scientists and policymakers [1]. It may have serious environmental impacts, yet it is a difficult problem for policymakers because it is surrounded by significant scientific uncertainties and could be expensive to address. It will have to be solved globally, even as impacts will need to be dealt with regionally and locally. It has the potential to affect multiple sectors with different intensity across regions and time. And it involves significant interrelationships among physical, social, economic, political, and other factors.

Climate change has more to do with the success of the human enterprise than its failures. Industrial civilization, with its heavy reliance on fossil fuels, inadvertently created the problem of human-induced climate change. The emission of greenhouse gases due to human activities enhances the natural greenhouse effect, resulting in a human influence on climate that augments natural climate variability and change. The same process of scientific and technological development also created interconnected human communities of unprecedented size, with areas of high population density and

1 The views expressed are the author's own and do not represent the official policy of the US Environmental Protection Agency.

large-scale and rapid population movements. The potential for emerging and re-emerging diseases to spread quickly has greatly increased with the advent of modern air travel and the creation of large human settlements. The potential for such diseases to become endemic may increase.

Human societies have experience with adaptation, having responded with varying degrees of success to climate variability and extreme events. In addition, large-scale human migration has exposed people to very different climates, sometimes within a short time frame, as in the case of transoceanic or transcontinental migrations. It is a testament to human ingenuity and adaptability that viable societies have been established and flourished in a very wide range of climatic environments, given sufficient resources. However, anthropogenic climate change presents a substantial new challenge for the field of public health and for other sectors.

Coping with the potential effects of climate change will be a complex and ongoing process requiring action by individuals, communities, governments, and international agencies. One way to respond is through adaptation intended to increase the resilience of societies and ecosystems to change. Rapid social and technological adaptation is becoming an increasingly important challenge because climate is now projected to change at a faster rate. The effectiveness of adaptation will determine the degree to which individuals and communities will be affected by climate-sensitive health outcomes with a changing climate. Failure to invest in adaptation may leave a nation poorly prepared to cope with adverse changes and increase the probability of severe consequences [2]. Therefore, adaptation strategies, policies, and measures need to be considered as part of any larger policy portfolio.

The extent to which society is willing to expend resources to avoid the effects of climate change will depend in part on its perceptions of the risks posed by climate change, the perceived costs of the effort, ability to pay, and how much it is willing to risk possible negative consequences [3,4]. Because resources need to be shared among a variety of public health problems, along with other problems of concern to society, the ideal situation is to direct resources to their highest valued use to do the greatest public good [5]. This, of course, is a social choice, not a scientific decision. Stakeholders may have conflicting desires, and conflict resolution is likely to be required. Policymakers will have to consider issues of equity (e.g., a decision that leads to differential health impacts among different demographic groups), efficiency (e.g., targeting those programs that will yield the greatest improvements to public health), and political feasibility.

Policy makers outside the public health community are faced with similar challenges. Policy makers dealing with multiple social objectives (e.g., elimination of poverty, support for agriculture, promotion of economic growth, protection of cultural resources) and competing stakeholder desires must make difficult choices as they allocate scarce human and financial resources [5]. For this reason, the Intergovernmental Panel on Climate Change (IPCC) suggested that it is useful to view climate change as part of the larger challenge of sustainable development [6]. Climate policies – including those intended to protect public health – can be more effective when consistently embedded within broader strategies designed to make national and regional development paths more sustainable. The impact of climate variability and change, climate policy responses, and associated socioeconomic development will affect the ability of communities to achieve development goals. Conversely, the pursuit of sustainable development goals will affect the opportunities for, and success of, climate policies.

The development of adaptation strategies is complicated by the fact that significant uncertainties exist about the underlying science, the geographic and temporal scales of consequences, and the effectiveness of available response strategies. A major issue facing scientists and policymakers is how to communicate the scientific information that is available, the degree of certainty associated with this information, and the implications of uncertainties for the issues of concern to decision makers, resource managers, and other stakeholders. There are two dangers. One is that in the absence of sufficient and accurate information, or the absence of a compelling case for action, the public may take little interest and not respond effectively. This is one reason why governments and intergovernmental agencies spend time and money to raise public awareness and to inform the public as to potential risks and benefits. The other danger is over-reaction. Once an issue (a risk or a threat) becomes the focus of public attention, there can be a high demand for information, reassurance, and action. Given the complexities and uncertainties associated with climate change, and the aversion of the public to involuntary risks, facilitating an informed and thoughtful public response could become as difficult as managing the risk itself.

We next explore lessons from the history of climate adaptation and public health management in an effort to better understand how scientific knowledge and management practices can be combined to more effectively address the potential impacts of climate change.

3. LESSONS LEARNED FROM THE CASE STUDIES

Evaluating, designing, and implementing an effective adaptation strategy are complex undertakings. Policy makers should not be cavalier about the ease with which adaptation can be achieved, or the expected effectiveness of any policies implemented. Not only must the potential health impacts of climate change and options for responding to these impacts be identified, but barriers to successful adaptation and the means of overcoming such barriers also need to be evaluated [5].

The wide and varied experiences in coping with climate and other risks to human health provide a number of useful lessons on the process of adaptation that may have value to other sectors as they confront the challenges and opportunities of climate change. This section briefly summarizes some of the lessons from the case studies presented in this book that can provide guidance for the design and implementation of effective and efficient adaptation strategies, policies, and measures. The main lessons can be grouped into the following five themes:

- The design of adaptation strategies, policies, and measures must be based on an understanding of the multiple and interacting determinants of disease. Climate change may exacerbate or ameliorate disease determinants, with the possibility that thresholds or nonlinearities may be encountered. Increased understanding of the health impacts of current climate variability is likely to facilitate adaptation to future climatic conditions.
- Multiple political, social, economic, technological, and human factors determine whether adaptation strategies, policies, and measures are effective. Effective interventions are embedded in an understanding of human factors and are tailored to local situations. Also, maladaptation and unintended consequences of interventions can occur in many different ways.

- Surveillance and early warning systems, coupled with effective response capabilities, can reduce current and future vulnerability.
- Adaptation is a process that requires sustained commitment. Because health risks and their drivers change over time, monitoring and evaluating interventions are important. It is prudent to intervene on a small scale to test the effectiveness of solutions before large-scale deployment.
- Collaboration and coordination are required across sectors.

One of the underlying themes throughout the book is the need to establish an institutional structure with the responsibility to maintain vigilance in responding to climate change, and to commit sufficient resources on an ongoing basis to identify and respond to problems. The aphorism of acting in haste and repenting at leisure applies here, with the caveat that the consequences of a less than effective intervention can be severe in terms of human disease and death. There should be skepticism about adopting quick-fix solutions that promise to permanently solve problems. It is not that such solutions cannot happen, but that we must be wary of them because of incomplete understanding of problems and proposed solutions, inadequate research into appropriate approaches to implementation, and the fact that the situation can change and new or old problems can emerge. However, decisions must be made. The question is how best to make decisions despite the existence of uncertainties.

Below, we briefly discuss each main lesson with specific examples drawn from the chapters in this volume.

The design of adaptations strategies, policies, and measures must be based on an understanding of the multiple and interacting determinants of disease. Climate change may exacerbate or ameliorate disease determinants, with the possibility that thresholds or nonlinearities may be encountered. Increased understanding of the health impacts of current climate variability is likely to facilitate adaptation to future climatic conditions.

Climate change is only one of many factors influencing human health and social well-being. The ecological, socioeconomic, and climate systems are closely linked, which poses a challenge for policymakers. Before designing and initiating an intervention, it is critical to gather information to understand the multiple and interacting determinants of disease, including both the immediate causes of the disease (e.g., a heat wave can increase morbidity and mortality) and other drivers associated with the disease (e.g., increased urbanization can create an urban heat island that exacerbates the effect of a heat wave). Also, it is important to understand "contextual" determinants of the disease, including the larger societal drivers such as population growth, poverty, and ecosystem changes.

Poverty is an important driver of many diseases

In a number of the case studies, the widespread poverty of the population was a critical factor leading to high vulnerability to disease. One of the outcomes of poverty (although perhaps also a cause) is inadequate public health infrastructure and access to health care. The consequence is a reduced ability to prevent and treat diseases, resulting in situations where controlling the spread of disease is difficult. As is discussed

in the case studies on campylobacteriosis (Chapter 4) and arsenic (Chapter 5), poverty is generally associated with inadequate sanitation, which can lead to exposure to water-borne diseases.

The role poverty plays in creating vulnerability to climate change cuts across almost all climate sensitive sectors. Wealth is one of the determinants of adaptive capacity [7]. Substantially reducing or eliminating poverty would greatly enhance the ability of societies to cope with many aspects of climate variability and change, and perhaps dramatically reduce vulnerability. However, reducing poverty alone will not eliminate vulnerability, as demonstrated by the many excess deaths during the European heat wave in 2003. Socioeconomic, political, and cultural considerations are examples of factors other than wealth that also influence vulnerability.

Ecosystem changes can facilitate the emergence and re-emergence of disease

Climate change can change or disrupt natural systems, making it possible for diseases to spread or emerge in areas where they had been limited or had not existed, or for diseases to disappear from areas that are no longer hospitable to the vector or the pathogen. Climate is one of multiple factors that determine the range of a disease; land use change is another major determinant. For example, campylobacteriosis is an "emerging" human gastrointestinal disease, with a dramatic increase in cases in the last few decades. In New Zealand, natural vegetation was replaced with pastoral farming. This increased sources for disease (animal waste) and reduced the ability of natural vegetation to remove the wastes from runoff. This has resulted in contamination of half of New Zealand's rivers and streams (see Chapter 4). In another example, Githeko and Schiff (Chapter 7) report that land use changes in Africa, such as deforestation in Tanzania and cultivation of swamps in Uganda, have been associated with the spread of malaria. Not all changes in land use have adverse consequences for human health; draining wetlands near human settlements can reduce habitats for disease-carrying mosquitoes.

This lesson also applies to sectors other than public health. For example, ecosystem changes may result in the spread of pests that can affect agricultural output. Using pesticides to control these pests can, in turn, increase the costs of agricultural production. And if climate change increases the frequency and intensity of rainfall events, there could be more runoff of pesticides from farms into rivers and streams, affecting water quality and wildlife. It is therefore critical that the effects of ecosystem changes be identified and that our understanding of the mechanisms through which these changes occur be improved.

Increased understanding of the health impacts of current climate variability is likely to facilitate adaptation to future climatic conditions

Climate change can be expected to change the location, frequency, and intensity of known health risks. Part of the preparation to address the potential impacts of climate change is to improve our understanding of risks from the current climatic conditions,

such as those posed by heat waves (Chapter 8) and other extreme weather events (Chapter 9). In addition, as a number of chapters in this book point out, better understanding of potential risks from climate variability and change, and of the populations vulnerable to those risks, can help health authorities target surveillance, response, and other programs.

The importance of understanding risks from current climate and how the risks could change is borne out in other climate sensitive sectors. For example, the risks posed by climate variability to water resources are not new to societies, but changes in the frequency and intensity of precipitation might require modification of current water management practices.

Multiple political, social, economic, technological, and human factors determine whether adaptation strategies, policies, and measures are effective. Effective interventions are embedded in an understanding of human factors and are tailored to local situations. Also, maladaptation and unintended consequences of interventions can occur in many different ways.

Many of the chapters in this book demonstrate the need to design appropriate interventions tailored to local circumstances. Differences in culture, education, knowledge, availability and affordability of technology, and other factors mean that a "one size fits all" approach is likely to fail. The specific lessons learned include the following:

Changing the behavior of individuals may be difficult

Adaptations that require individuals to change their behavior may be difficult to successfully implement. Githeko and Shiff (Chapter 7) note that despite the demonstration that use of treated bed nets reduces the risk of malaria, their acceptability and affordability have been a barrier to adoption. Lucas and McMichael (Chapter 11) note that convincing individuals to change their behavior (reducing exposure to harmful UVB rays from the sun) can be challenging if the change involves inconvenience or increased cost, although information campaigns to reduce UVB exposure have had some success. (They note, however, that maladaptation could occur if the campaigns reduce sun exposure too much, limiting UVR exposure necessary to manufacture vitamin D.) In Chapter 12, Linder discusses the difficulties that can be encountered when encouraging or even coercing individuals to change behavior.

The fact that individuals do not readily change their behavior is a challenge for all sectors. Successful campaigns to change individual behavior such as anti-smoking or anti-drunk driving efforts often started with strong stakeholder involvement (such as Mothers Against Drunk Driving), took years to succeed, and required not just public appeals but also incentives such as higher cigarette prices or stricter drunk driving laws. This suggests that efforts to change individual behavior need to be undertaken, sometimes with incentives, in a sustained manner involving messages targeted to specific population subgroups. Better understanding of what has worked and why (and what has not worked and why not) can facilitate the development of more effective intervention programs.

Be wary of "simple solutions", particularly technological responses that have not adequately accounted for potential behavioral responses and other socioeconomic, cultural, and human factors

It can be tempting to adopt simple solutions that sound as if they would readily solve a problem, particularly when the proposed solution is a technological one. The tubewells installed to reduce morbidity and mortality from diarrheal diseases, particularly among children (Chapter 5), is a good example of such a solution. It was probably quite tempting to latch on to this technological solution without investigating such complicated matters as how people actually used water, their beliefs about water and disease, whether or not people would accept tubewells, and whether the solution would create other problems.

Effective interventions must be tailored to local situations

The discussion in Chapter 5 on arsenic in Bangladesh has a number of valuable lessons; among them is the importance of designing an intervention so that it is appropriate for the local situation. This is particularly the case for technological solutions. If the remedy is incompatible with local culture, it is unlikely to be adopted. Other factors also need to be considered, such as the local availability of resources; preferences that are a function of culture, traditions, religion, and other factors; the relative size of a vulnerable population (e.g., more elderly in one region than in another); equity considerations; and political feasibility. Also, as noted earlier, different stakeholders have different, and perhaps competing, objectives, which can make the choice of specific adaptation measures difficult.

Githeko and Shiff (Chapter 7) write about malaria:

> There has been a very high expectation of a magic bullet coming out of hi-tech laboratories (e.g., vaccines, genetically modified mosquitoes) and as a result, African malariologists have failed to optimize the use of existing tools such as selective indoor spraying of houses at the foci of transmission in the highlands. Sufficient knowledge exists to modify houses to make them less accessible to mosquito vectors, yet this knowledge has been completely unutilized …. It is our view that Africa can develop some simple homegrown and scientifically sound solutions for malaria transmission.

Tubewells were used in Bangladesh as a solution to polluted surface water supplies. However, many people refused to obtain water from them. This highlights the importance, not just of considering the culture one is operating within, but also of working with regional and local stakeholders in the design of interventions (see Chapter 9). This may mean more than simply consulting stakeholders, but empowering them to make decisions about appropriate responses.

This is an important message for adaptation in all climate-sensitive sectors. Whether they are responding to sea level rise, change in crop yields, loss of biodiversity, or many of the other impacts of climate change, adaptation strategies that do not consider local circumstances can lead to lack of use, misapplication, and unintended consequences.

Maladaptation and unintended consequences can occur in many different ways

Maladaptation occurs when current practices or behavior increase rather than decrease climate risks or risks from other stressors [8]. Maladaptation also occurs when interventions are implemented and scarce resources are used when adaptation was not necessary.

Addressing maladaptation where it already has occurred can produce a "win-win" outcome: the interventions can address a situation that is a problem under current climate and can improve the ability to adapt to the potential impacts of climate change. For example, Weinstein and Woodward note in Chapter 4 that maladaptation arose as a consequence of past management of water catchments, and that improving management, including revegetation with an emphasis on planting native species, would have multiple benefits, independent of climate trajectories, on reducing the prevalence of campylobacteriosis in New Zealand. Some of these adaptations would produce immediate benefits, such as reduced runoff and improved water quality.

The potential for maladaptation in other sectors has been studied [7,8]. One approach suggests that existing practices that yield unintended consequences (i.e., existing maladaptation) should be addressed now because they exacerbate or introduce risks, and there would be immediate benefits if corrected. Furthermore, such corrections will improve society's ability to adapt to future climate change (although additional adaptations may well be needed). Even if maladaptation is not occurring under current climate, it could arise over time with changing conditions. Systems that are well adapted now may become more vulnerable in the future as the climate changes. For this reason, ongoing monitoring and evaluation of implemented adaptation measures is needed.

It is important to understand the political, social, economic, and other forces that may affect implementation

Scientific information is only one input into policy decisions. Selection and implementation of adaptation strategies, policies, and measures are done within a political, social, and economic context. Understanding this context, and incorporating modifications to address this context, can facilitate the acceptability of desirable adaptations.

Among the major ethical issues facing public health is the matter of individual rights versus the good of society as a whole. One situation is where an individual can pose a risk to society as a whole (see Chapter 1). The typical public health response is to place the welfare of society above that of the individual. For example, the freedom of movement of an individual carrying an infectious disease can be limited to reduce the risk of spreading the contagion. Weinstein and Woodward (Chapter 4) raise another ethical dilemma: the problem of investing relatively large sums of money to protect a few individuals. They point out that drinking water quality problems may be greatest in poor isolated communities, where solutions on a per capita basis are expensive. Considerations of equity may demand investment in such cost-ineffective solutions.

Such ethical dilemmas arise in other sectors addressing climate variability and climate change. Certain individuals or subpopulations may have greater exposure to climate risks than society as a whole. A dilemma is whether it is better to invest large amounts of resources to protect the lifestyles of those individuals or better to take other measures such as to relocate them (or do nothing), which also has monetary costs.

Surveillance and early warning systems, coupled with effective response capabilities, can reduce current and future vulnerability.

Surveillance is an important resource for identifying risks

In Chapter 10, Wilson and Anker state, "Disease and weather surveillance are critical components of efforts to measure, recognize, evaluate, anticipate, and respond to climate effects on health". Surveillance systems are designed to provide early intelligence on the re-emergence of health risks at specific locations in time for effective responses to be mounted. Climate change can be expected to facilitate changes in the geographic range, seasonality, and duration of a variety of health outcomes such as malaria, dengue fever, and other vector-borne diseases (see Chapter 3). It may also introduce new risks.

Appropriately designed surveillance systems can identify risks to health, whether they are the result of climate change or other driving forces. However, to capitalize on this possibility, conventional surveillance systems need to account for and anticipate the potential effects of climate change. Surveillance systems will need to be implemented in locations where changes in weather and climate may foster the spread of climate-sensitive diseases and vectors into new regions. (Similarly, information about the timing, location, and potential severity of possible changes in climate-sensitive sectors other than public health can be used to prioritize the placement of surveillance and early warning systems to alert populations to changing risk conditions.) Increased understanding is needed of how to design these systems where there is limited understanding of the interactions of climate, ecosystems, and infectious diseases.

Early warning systems can reduce current and future vulnerability

Whereas surveillance systems are designed to detect and investigate disease outbreaks as they occur, early warning systems are designed to alert the population and relevant authorities that a disease outbreak is expected. Early warning systems can be very effective in preventing deaths, diseases, and injuries. One component of an early warning system, pointed out by Woodruff in Chapter 6, is disease prediction. The effectiveness of the prediction component depends on:

- an understanding of the mechanisms of disease transmission;
- reliable and up-to-date information on exposures and health outcomes; and
- a model that is accurate, specific, and timely.

As Woodruff discusses, knowledge of disease transmission requires an understanding of the causes of the disease. Being able to predict disease outbreaks requires good historical data on which to base the prediction, as well as reliable and up-to-date monitoring data. The model needs to be sufficiently accurate and valid for the use to which it is put. Models for early warning systems typically work best for episodic diseases rather than endemic ones.

Early warning is also important for extreme climate events. Street et al. in Chapter 9 point out how early warning can be critical for avoiding natural disasters such as hurricanes. Kovats and Koppe in Chapter 8 discuss the use of heat health warning systems to predict extreme heat waves that will pose a risk to health.

Risk prediction must be coupled with adequate response capabilities

An early warning of a problem will be inadequate if it is not accompanied by an effective response capability, including a specific intervention plan. In Chapter 6 Woodruff states, "Excellent predictive ability is of little value if the response capacity is not equally as good". Once a warning is given, the public health system must have the capability to take effective measures to reduce the predicted risks. Kovats and Koppe point out in Chapter 8 that the combination of a heat watch warning system and a response plan to reduce the exposure of vulnerable population groups to extreme heat led to a substantial reduction in deaths from extreme heat in Chicago in 1999. Street et al. in Chapter 9 discuss the importance of including communities in planning responses to extreme weather events.

Woodruff identifies the following necessary components of a response plan (applicable to all climate-sensitive sectors):

- details on thresholds for action;
- available and effective interventions;
- an economic assessment of the benefit and affordability of the system;
- a communication strategy; and
- involvement of all relevant stakeholders in the process.

Adaptation is a process that requires sustained commitment. Because health risks and their drivers change over time, monitoring and evaluation of interventions are important. It is prudent to intervene on a small scale to test the effectiveness of solutions before large-scale deployment.

This is a lesson of unwavering vigilance. Societies must not become complacent and assume that problems are solved forever, but must maintain efforts to monitor and evaluate the problems and their solutions.

Health risks and their drivers change over time

Effective public health management must address changes in drivers or the disease itself in a prompt and efficient manner. The burden of diseases such as malaria can increase with changes such as the development of drug-resistant parasites and pesticide-resistant vectors (see Chapters 3 and 7). Changing population demographics, particularly increasing numbers of individuals over age 65, suggest that there will be increased vulnerability to a number of the potential health impacts of climate change (e.g., death due to heat stress as the frequency and intensity of heat waves increase). Changes in land use, such as conversion of forest to rice cultivation, can create favorable conditions for disease vectors.

Socioeconomic conditions can change, resulting in the easing, exacerbation, or creation of new health problems. For example, Weinstein and Woodward in Chapter 4 identify increasing social inequality as a possible cause of greater exposure to water-borne diseases. In contrast, improved social conditions can result in more favorable conditions to implementing actions to reduce a disease risk [9].

A sustained commitment is required

In their analysis of the reemergence of yellow fever, dengue/dengue hemorrhagic fever, and malaria, particularly in the Americas, Gubler and Wilson (Chapter 3) make a strong case for the importance of a sustained commitment. Mosquito control programs in the 1940s and 1950s resulted in effective control of the diseases in the Americas because mosquitoes carrying the diseases were controlled. This success unfortunately bred complacency and control measures were relaxed (and funds were diverted to other activities). In the 1960s and 1970s, these diseases reemerged.

Gubler and Wilson state that solid political will, adequate resources devoted to adaptation, and institutional commitments are needed to control health problems over the long term. One high-priority need is for adequate trained personnel and resources to be made available to countries where diseases are endemic and investments need to be maintained. The level of investment must address not only the burden of disease in that population but also the potential consequences if the disease moves across national boundaries (as was highlighted by the SARS outbreak of 2003).

A related lesson is that many diseases cannot be eliminated, but they can be controlled. Both Gubler and Wilson (Chapter 3) and Githeko and Schiff (Chapter 7) conclude that we should strive to control and limit diseases such as malaria rather than try to eliminate them. Gubler and Wilson state that elimination of *Anopheles* and *Aedes* mosquitoes is technologically impossible. A vaccine for malaria or dengue also does not exist. They point out the need to maintain the political will to continue disease control programs even when it appears that a disease is under control.

A strategy of eternal vigilance is difficult to follow. Once a problem is sufficiently reduced in scope that it fades from public consciousness, other problems emerge to take its place. We can assume that, in addition to having limited resources, there is a public attention budget that focuses on only a limited number of problems at one time. If a problem has insufficient immediate risk to keep it prominent in the public and political eye, other problems are likely to displace it and to attract financial support.

Intervention on a small scale is warranted to test the effectiveness of a "solution"

An intervention, particularly something new, should be tested on a small scale. Testing can identify potential implementation problems or unintended consequences (e.g., for a new technology). Testing of tubewells in Bangladesh might have identified the high arsenic levels in groundwater, in addition to the difficulties in getting people to properly use the wells. The lessons learned during the testing period can then be applied when an intervention is scaled up.

Monitoring and evaluation of interventions is important

Many of the chapters in this book point out the importance of monitoring and evaluation of interventions. We cannot assume that the interventions implemented will work and will do so in perpetuity. The only way to find out if solutions are working is to monitor the health outcomes. In addition, monitoring and evaluation can identify unanticipated problems. As is noted in Chapter 10 on surveillance, we can count on surprises in a rapidly changing world. Monitoring can identify where solutions

have not worked and where further interventions are needed. Evaluation can identify why particular solutions did and did not work. Both monitoring and evaluation are needed to ensure interventions continue to have the intended effect.

Collaboration and coordination are required across sectors

Strategies, policies, and measures for adaptation to climate variability and change in multiple sectors, including public health, are increasingly inseparable. If strong collaboration and coordination do not develop across different sectors and communities, then effective and efficient adaptation to climate change will be less likely, with needless human suffering. Most science is currently conducted within narrow disciplines. Multidisciplinary approaches are required to understand the potential risks and benefits of climate change, and the possible response strategies to protect and enhance human health and well-being in the face of what the future will bring. Taking a more systems-based approach allows the risks from climate change to be put into perspective with other drivers of disease, thus facilitating the identification of the most effective and efficient adaptation options.

4. INSIGHTS FOR POLICY

We turn to the question of what modifications to public health policies and systems might be necessary to enhance adaptive capacity to climate variability and change. To successfully modify public health policies and systems, several prerequisites must exist: an awareness that a problem exists; a sense that the problem matters; an understanding of the causes of the problem; an ability to influence the outcome; and political will to influence the problem [10]. These prerequisites for action can be addressed by education, research, and institutional development.

Public health officials and researchers must be educated to understand that climate is a risk factor for a range of diseases and that increasing resilience to current climate variability will be a step toward increasing adaptive capacity to future change. The climate is always changing, but it is projected to change at an increasingly more rapid rate in the future. This change may be accompanied by increasing climate variability. The resulting increase in floods, droughts, heat waves, etc., would strain the ability of public health systems worldwide to cope unless proactive policies are formulated and implemented.

Research is needed to better understand the relationships between climate and health, and how these relationships could be effectively modified or influenced. Such investments will provide the policy-relevant information needed by decision makers to formulate and implement appropriate response options. In addition, to design effective adaptation options, research is needed to understand which public health interventions have and have not worked in the past, and why. Public health can use the lessons learned to inform the design of future interventions and the processes by which they are implemented.

Because climate change will continue for the foreseeable future and because adaptation to these changes will be an ongoing process, institutions need to be developed with the responsibility for consistently and effectively factoring climate variability and change into all policies. Active management of the risks and benefits of climate change needs to be mainstreamed into the design and implementation of disease control strategies

and policies across the institutions and agencies responsible for maintaining and improving population health. Some risk management activities will be extensions of current public health approaches that can be designed within existing operational responsibilities. For example, the design and implementation of early warning systems for climate-sensitive diseases is a win-win strategy that would reduce the current burden of disease while increasing adaptive capacity if the incidence of disease increases. Other risk management activities will require modifications to current public health practices or systems. For example, a number of studies have suggested that the changing temperature and precipitation patterns projected to occur with climate change could increase the current range of epidemic malaria in Africa [6]. Development of closer collaboration between public health and meteorological agencies is needed in the placement of long-term monitoring stations to ensure that prevention activities are proactively implemented.

The precise modifications needed to public health policies will depend on factors such as:

- the health outcome;
- the expected severity of the climate impact;
- the location;
- the timing of when the impact is likely to occur;
- the effectiveness of measures in place to cope with the impact;
- other stressors that could increase or decrease resilience to impacts;
- the capacity of the population to cope with the impact; and
- who is expected to take action.

5. CONCLUSION

Some have argued that the existence of scientific uncertainties precludes policy makers from taking action today in anticipation of climate change. This is not true. In fact, policy makers, resource managers, and other stakeholders make decisions every day despite the existence of uncertainties. The outcomes of these decisions may be affected by climate change. Or the decisions may foreclose future opportunities to adapt to climate change.

Public health has a long history of effectively intervening to reduce risks to the health of individuals and communities. The increasing understanding of the ways that weather and climate variability are likely to change over the coming decades offers an opportunity to proactively design and implement adaptation strategies, policies, and measures to reduce projected future burdens of climate sensitive diseases.

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