City Health System Preparedness to Changes in Dengue Fever Attributable To Climate Change: An Exploratory Case Study

Jostacio M. Lapitan,* Pauline Brocard, Rifat Atun, Chawalit Tantinimitkul

Summary

City health system preparedness to changes in dengue fever attributable to climate change was explored in this collaborative study by Imperial College London and WHO Kobe Centre. A new toolkit was developed and an exploratory case study in Bangkok, Thailand was undertaken in 2008. This study found that there is a clear lack of research in this area, as most research looked at impacts and not at responses and preparedness for effective response. There is also a clear need to develop and/or scale up national-capital city efforts to assess and address the implications of climate change for health systems. It recommends further case studies to validate the toolkit and generate guidelines on how to develop effective response plans.

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1. INTRODUCTION

The year 2007 marked the first time in history that 50% or more of the world's population lives in urban settings. 2007 was also the year that the science on climate change became unequivocal: the Earth is warming, as verified by the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC). Projections for increasing health impacts from accelerating climate change coincide with continuing trends of rapid, unplanned urbanization, signaling significant threats to public health. Climate change and its health impacts on vulnerable populations in urban settings are burning issues for development workers and disaster risk managers alike.

There is a significant increase in human mortality and morbidity as a result of climate change (Campbell-Lendrum and Woodruff 2007; Ebi et al. 2006; Patz et al. 2005; WHO 2003). Extreme weather conditions, such as heat waves, floods, storms, fires, droughts are occurring as a result of climate change (Campbell-Lendrum and Woodruff 2007; Campbell-Lendrum 2006; Hajat 2006; IPCC 2007; Patz 2002; Patz 2005; Vorosmarty 2000; WHO 2003; WHO World Health Day 2008). Increasingly, changes in global and regional climate patterns are affecting the dynamics and location of infectious diseases such as malaria, dengue fever, encephalitis, cholera, amongst others (Campbell-Lendrum and Woodruff 2007; Campbell-Lendrum 1996; Ebi 2006; IPCC 2007; Lipp 2002; Patz 2002; Patz 2005; WHO 2003; WHO World Health Day 2008).

The main aim of this paper is to better understand the complexities associated with health system preparedness and planning in the context of changes in dengue fever epidemiology. The current body of research on dengue fever is concerned primarily with the upstream impacts of climate change and there is a clear lack of research on response. "Anticipatory prevention is better than reacting once a disease outbreak has occurred" (Bulto 2006). This systematic review of current response and preparedness to changes in dengue fever epidemics associated with climate change illustrates gaps in the literature and highlights the importance of this study. In this paper, we review previous research on increasing health plan preparedness for dengue fever, develop a toolkit to assess preparedness, and provide a case study of Bangkok, Thailand.

2. BACKGROUND & LITERATURE REVIEW

Dengue fever, also known as breakbone fever, causes a flu-like illness, and infects approximately 50 million people worldwide per year (WHO 2008). There are four serotypes of dengue fever. Patients who have had dengue have immunity for life from the serotype they have caught. However, patients who
are infected with a second serotype are more likely to get dengue haemorrhagic fever (DHF) (WHO 2008). Dengue haemorrhagic fever is a more virulent form of dengue fever, and has potentially lethal complications (WHO 2008).

Dengue is a vector-borne disease, with its main vector being the *Aedes aegypti* mosquito. Dengue persists mostly in the tropical and subtropical regions of the world where the temperature and rainfall are adequate for the mosquitoes to thrive and breed (see Figure 1). It is an urban disease, with the vectors breeding mainly in water located in containers (Gubler, D.J., et al., 2001). Dengue fever is cyclical, with seasonal variations as well as bigger outbreak cycles every 2-3 years (WHO 2008, 2004a; Rodriguez-Tan and Weir 1998; Lifson 1996).

**FIGURE 1**
Worldwide Distribution of Dengue (WHO 2008)

It is difficult to estimate the exact prevalence and incidence of dengue fever because only 30% of cases are symptomatic (Chen and Wilson 2005). The remaining 70% are either asymptomatic or produce only mild symptoms such as a low fever (Chen and Wilson 2005). Quick, commercially available diagnostic kits for dengue are relatively limited in developing countries. As a
result doctors must treat patients for dengue fever symptoms without having a confirmed diagnosis. Incidence and prevalence of dengue hemorrhagic fever (DHF) is easier to estimate because all cases require hospitalization.

### 2.1 Dengue Control and Management

The potential control measures for dengue can be categorized by surveillance of the vector, control of the vector, and monitoring and evaluation of vector control (Figure 2), based on the WHO guidelines for dengue fever and DHF control (WHO 2003).

**FIGURE 2**  
Vector Control for Dengue Fever

Climate change will lead to shifts in the prevalence and distribution of vector-borne diseases including dengue fever, and potentially has already caused some epidemiologic changes (Lifson 1996; Khasnis 2005; Gubler 2001; Sutherst 2004; Ye 2007). Dengue prevalence is likely to be affected by climate change due to the fact that the mosquito vector is cold-blooded and therefore more sensitive to changes in temperature, humidity and precipitation (Lifson 1996; Khasnis 2005; Lindsay 1996; Tanser 2003; Martens 1995; Hales 2002). The preponderance of the four flavivirus serotypes are associated with higher temperatures. The abundance and bite rate of *Aedes aegypti* mosquitoes, which

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The text continues with a detailed explanation of vector control and management strategies, as well as the implications of climate change on dengue prevalence. The diagram in Figure 2 illustrates the steps involved in vector control, surveillance, and monitoring, highlighting critical interventions such as habitat management, insecticide use, and public health measures. The integration of these strategies is essential in managing dengue outbreaks.

### References

- Lindsay, S. (1996).
transmit dengue fever by feeding during the day, are also affected by temperature, humidity and precipitation (Lifson 1996; Hales 2002; Hales 1999).

Describing the future of the environment and health process in Europe, the Fourth Ministerial Conference on Environment and Health stated “health aspects are still not well integrated into international and national initiatives, strategies, and action plans on sustainable development” (WHO 2004b) and that “A comprehensive strategy to support a public health response is conspicuously lacking” (Campbell-Lendrum and Woodruff 2007). This is a significant issue of concern and has been propelled forward by the agendas set in the recent WHO World Health Day 2008, report on climate change and health (WHO 2003a, 2008; Matthies 2008). Another catalyst for health preparedness was the publication of the 2008 World Bank guide, *How to climate-proof our cities* (World Bank 2008).

### 2.2. Literature Review

For the purpose of this paper, we conducted a systematic review of health system responses to changes in dengue fever as a result of climate change. The review follows the Cochrane criteria, with the goal of creating a clear, structured report, with repeatable results (*The Cochrane Collaboration*). The review emphasizes the importance of context, and ultimately contributed to the development of the toolkit. The data sources used were EBSCO Business Source Complete with Business Searching Interface, Factiva, GreenFILE, Health Management Information Consortium International (HMIC) July 2008, JSTOR, Ovid Journals@Ovid Full Text June 09, 2008, and PubMed. To help ensure the quality of the data, only peer-reviewed publications were explored. A diversity of studies were included, such as randomized control trials and studies on response and preparedness to dengue fever.

The majority of the studies we reviewed explored the general health impacts associated with climate change and concentrated on vector-borne diseases. Only two of the reviews concentrated specifically on dengue fever, however they both only briefly mentioned climate change. Out of the four studies that collected data, three collected weather and climate data, two collected dengue data, two collected mosquito data, two collected socioeconomic data, and one collected response/adaptation data. Table 1 summarizes the characteristics of the studies included in the review.

Bulto et al. (2006), explored climate variability and *Aedes aegypti* and predicted “more frequent epidemic outbreaks and a change in the season and spatial pattern of dengue fever” in Cuba. In response to their results, the researchers suggested the use of climate projections to inform future policy decisions concerning the development of vector control programs.

Hales et al. (1999), investigated the relationship between the El Niño southern oscillation (ENSO) and dengue fever, and concluded that ENSO may trigger dengue fever outbreaks on large populated islands.
Woodruff et al. (2006) projected the spread of dengue in Australia as a result of increased temperatures on the basis of “no policy action” to reduce greenhouse gas emissions. Their conclusions were that strong policy action to reduce emissions would prevent further expansion of dengue fever (Woodruff 2006).

Rawlins et al. (2007) collected primarily response data and explored community knowledge of climate change issues as well as community willingness to help control dengue fever in the Caribbean. Understanding and awareness of climate and health issues were found to be high, but involvement was anticipated only to occur with greater levels of community persuasion.

None of the studies we reviewed had explored health system responsiveness to changes in dengue fever as a result of climate change. The majority of the studies focused either on the impacts of climate change on dengue fever outbreaks and patterns (Hales et al. 1999; Bultó et al. 2006), on the impacts of climate change policies on dengue fever distribution (Woodruff 2006), or on community knowledge and willingness to participate in vector control methods (Rawlins et al. 2007). Overall, while the awareness of potential vector control methods exists (Table 2), there is a clear gap in the literature about responding to changes in dengue fever as a result of climate change and also with regard to monitoring and evaluation.

### TABLE 1
Characteristics of Studies Included in Dengue Fever Review

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>Countries or Regions</th>
<th>Weather and climate data</th>
<th>Epidemiologic data</th>
<th>Ecologic data</th>
<th>Socio-economic data</th>
<th>Responses / Adaptation data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bultó et al.</td>
<td>2006</td>
<td>Cuba</td>
<td>Collected</td>
<td>None</td>
<td>Aeotex aspori collected</td>
<td>Collected</td>
<td>None</td>
</tr>
<tr>
<td>Campbell-Lendrum and Woodruff</td>
<td>2006</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Franklin et al.</td>
<td>2008</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Guiter et al.</td>
<td>2001</td>
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<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
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<tr>
<td>Hales et al.</td>
<td>1999</td>
<td>South Pacific</td>
<td>Collected</td>
<td>Dengue fever cases</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Lifson</td>
<td>1999</td>
<td>United States</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
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<tr>
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<td>2002</td>
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<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Patt et al.</td>
<td>2000</td>
<td>None</td>
<td>None</td>
<td>Vector population and habitats</td>
<td>Collected</td>
<td>Community knowledge and willingness</td>
<td></td>
</tr>
<tr>
<td>Rawlins et al.</td>
<td>2007</td>
<td>Caribbean</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Rodriguez-Tan and Waier</td>
<td>1998</td>
<td>United States</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Sutphen</td>
<td>2004</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Woodruff et al.</td>
<td>2006</td>
<td>Australia</td>
<td>Collected</td>
<td>Dengue transmission patterns</td>
<td>None</td>
<td>None</td>
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</tr>
</tbody>
</table>
3. METHODOLOGY

This study was carried out by principal investigators Prof Rifat Atun and Dr Pauline Brocard of the Imperial College London in collaboration with the World Health Organization (WHO) Centre for Health Development (WHO Kobe Centre – WKC), Japan. The researchers identified the need for an assessment tool for health system preparedness in the context of dengue fever and climate change. Therefore, the study focused on three components:

- A systematic review of the health plan preparedness for changes in dengue fever as a result of climate change (see Section 2 above);
- The development of a toolkit to assess preparedness; and
- A case study of Bangkok, Thailand.

This study is significant because understanding and exploring the gaps or bottlenecks in preparedness is critical to protecting communities from the increasing dengue fever threat. Research findings can inform, advise and guide countries and cities on how to increase their levels of preparedness.

### TABLE 1
Vector Control Methods Discussed in Included Studies of Dengue Fever Review

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>Selective vector control</th>
<th>Vector modification</th>
<th>Immunity induction</th>
<th>Environmental manipulation</th>
<th>Zoonotic transmission control</th>
<th>Total control</th>
<th>Other</th>
<th>Total</th>
<th>Preparedness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bullo et al.</td>
<td>2008</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Campbell-Lendrum and Woodruff</td>
<td>2006</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frankel et al.</td>
<td>2008</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Gubler et al.</td>
<td>2001</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Hales et al.</td>
<td>1999</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td>Lim</td>
<td>1999</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Patz and Kraiga</td>
<td>2002</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Patz et al.</td>
<td>2000</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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</tr>
<tr>
<td>Rawlins et al.</td>
<td>2007</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Rodriguez-Tan and West</td>
<td>1998</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Yes</td>
</tr>
<tr>
<td>Rathore</td>
<td>2004</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Woodruff et al.</td>
<td>2006</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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</table>
This multidisciplinary, multi-method approach to assessment was primarily validated in a cross-sectional, cross-cultural setting. This work can inform interested researchers on the application of the toolkit, which has been successfully applied in Thailand. This study also assists in the evaluation of other cities' preparedness for changes in dengue fever due to climate change.

3.1 Toolkit Development

There are no current approaches for identifying the preparedness of national-capital city health systems for changes in dengue fever attributable to climate change. This toolkit was developed after carrying out systematic reviews and was based on the Systemic Rapid Assessment (SYSRA) and Systemic Rapid Assessment and Monitoring (SYSRAM) toolkits for tuberculosis and influenza developed by Professor Rifat Atun and his colleagues (Atun 2004, 2005; Coker 2004, 2006, 2007), and on other frameworks for evaluating public health system response to disasters including bioterrorism and heat waves (Landesman 2005; Bravata 2004; Bravata 2005; WHO 2005; Kovats 2006; Buehler 2004).

Although a number of guidelines and manuals exist for assessment, monitoring, and evaluation of vector control methods, they lack well-developed tools for enabling a response to climate-led variations in dengue fever (WHO 2003b, 2005, 2006a, 2006b). Despite the importance of an effective response to increasing incidences of dengue fever, no formally validated tool exists to perform a detailed assessment of preparedness. There is a dire need for a systemic, programmatic approach to analyzing preparedness to changes in dengue fever.

The specific goals of the toolkit are to analyze the organizational arrangements related to dengue fever, to investigate the capacity of health systems to respond to changes in dengue fever as a result of climate change, and to identify barriers and facilitators of effective response. The toolkit framework was developed by the researchers in collaboration with the WHO Centre for Health Development and was conceptualized after reviewing dengue fever control guidelines (WHO 2003b, 2005, 2006a, 2006b; Lloyd 2003), as well as the following:

- approaches for evaluating public health systems or programs (CDC 2001);
- public health responses to disasters (Landesman et al. 2005), such as bioterrorism (Bravata 2004; Bravata 2005), influenza pandemics (WHO 2005; Mounier-Jack 2006), and heatwaves (Matthies 2008; Kovats 2006);
- methods for early detection of outbreaks (Buehler 2004); and
Since the topic is broad, and involves many key players in different settings, the identification of an optimal response plan for vector-borne diseases was necessary to help guide interviewers and to aid in the recognition of gaps in response plans.

The toolkit facilitates the recording of relevant information from national documents, epidemiological and weather data, and key informant interviews. These include key documents pertaining to climate change in the country, and ministry of health plans in relation to responses to health impacts of climate change. National and regional data and trends for incidence and prevalence, as well as mortality, are sought and analyzed for changes and variances. Long-term weather data are also analyzed to ascertain any changes and trends.

3.2 Interviews

The questions for the interview were developed using the existing toolkits and response plans. The list of questions is used as a guide for the interviewer, and the questions asked depend largely on the knowledge and expertise of the person being interviewed. The progression of questions is dependent on the answers given by the respondent.

The process of using the toolkit involves the purposeful sampling of key actors involved in various health system functions at different administrative levels (e.g., national vs. regional). A mix of respondents from different organizations and backgrounds is required for a robust, qualitative response. All information provided by interviewees was confidential and non-attributable. The interviews were recorded in writing or via audiotape with the permission of the interviewee. Later, the interviews were transcribed verbatim for detailed thematic analysis.

Initially, an optimal response plan was created with key questions to assess the preparedness of health system to changes in dengue fever as a result of climate change. Having previously developed the dengue preparedness and climate change toolkit, the Bangkok case study served as practical test of our work. The toolkit has since been reviewed and revised.

4. BANGKOK CASE STUDY

The toolkit was tested on the Thai health system. Thailand was chosen for the case study because it is globally renowned for its well-functioning health system. Thailand is a middle-income developing country with an integrated health system and it is also being affected by climate change. In theory, because Thailand has integrated a number of diverse programs into its health system, we postulate that the country is relatively well-positioned to respond to climate change related shifts in dengue fever.
With the help of the WHO Centre for Health Development, the WHO Regional Office for South-East Asia, and the WHO Country Office Thailand, meetings were organized with key staff members at the Ministry of Public Health, Bangkok Metropolitan Administration (BMA), Faculty of Tropical Medicine and Faculty of Science of Mahidol University, and various Health Offices in the Ayutthaya province. Mahidol University was chosen because it is one of the leading universities in tropical medicine in Thailand and is home to the Regional Centre for Tropical Medicine for Southeast Asian Ministers of Education Organization (SEAMEO). Moreover, the University boasts several WHO Collaborating Centres.

In addition to understanding how a health system might be able to respond to changes in dengue fever as a result of climate change, the aim of this exploratory case study is to identify how a response might be initiated in the Thai health system as a result of perceived changes in the environment. Other key questions were: What systems are in place to cope with possible increases in incidence of dengue fever as a result of climate change? What are the thresholds? Who will make the decisions? To what extent is climate change associated with changes in disease incidence?

The interviews were conducted at multiple levels and involved multiple stakeholders. The researchers followed a triangulation and inductive approach as they were constantly discussing findings between meetings. Meetings were held in Bangkok with a total of 48 people, and included the following key informants from the Thai health system: the Director of the Bureau of Vector-borne Diseases at the Ministry of Public Health, Directors of Disease Control Division at several District Health Offices, the Director of SEAMEO TROPMED and the Dean of Faculty of Tropical Medicine, and a National Professional Officer at the WHO Thailand Office. The meetings were facilitated by Prof Rifat Atun and the interviews were sound-recorded and transcribed. After the meetings, Prof Atun and Dr Brocard discussed observations and identified key results, strengthening the case study. The meetings were focused on interpreting how Thailand is initiating a response to increased incidences of dengue fever as a result of climate change. Additionally, meetings were organized with provincial health offices to explore levels of understanding and awareness of these issues in the field. All the meetings were audio recorded with permission, and later transcribed. Direct quotes were referenced by institution name in order to maintain the anonymity of interviewees.

District-level dengue fever data were provided to the research team after the meetings. Because of the scale of the datasets, and because they did not include climate data, we were unable to conduct complex statistical analysis to identify underlying trends in seasonality and dengue incidence.
4.1 Perceived Impacts of Climate Change

Data show that rain and dengue fever are highly correlated (Faculty of Tropical Medicine). Dengue incidence increases and decreases every 1-3 years (Faculty of Tropical Medicine, WHO Thailand Office). This could be due to population immunity or different serotypes that cause more cases (Ayutthaya Provincial Office). In 2008 the Thai Ministry of Health reported that the number of cases increased by 40% compared to 2007. The Ministry has been issuing warnings about this since February 2008, as this is the dry season and usually very quiet (Faculty of Tropical Medicine).

Temperature has increased. It is difficult to say if this has affected the number of cases. However, scientific evidence shows that an increase in temperature cuts the disease incubation period, increasing the time in which infection can occur. Research also shows that the vector develops more quickly (Bureau of Vector-borne Diseases).

In Thailand, dengue outbreak alerts may begin to last all year as the disease becomes less seasonal. In 2008, the country dengue alert started in January, which is very unusual (WHO Thailand Office). The research community is uncertain about whether this trend is due to climate change or not. However, future research is taking us in the direction towards and analysis of this phenomenon (Sena District Health Office).

Our difficulty is that we cannot predict. We have not tried to collect the information to see what is the component contributed by the weather change (Faculty of Tropical Medicine). We do not know about decomposition analysis (controlling for seasonal cycles and longer term 2-3 year cycles (Bureau of Vector-borne Diseases).

4.2 Health System Preparedness

In Thailand, all diseases, except malaria, are integrated into health system concerns (Bureau of Vector-borne Diseases and WHO Country Office Thailand). Not all cases of dengue fever are reported, because only 10% of all patients have symptoms and/or go to a health centre. The other 90% of infected individuals do not go to a health centre because they experience mild to no symptoms (Bureau of Vector-borne Diseases). 100% of dengue hemorrhagic fever (DHF) cases are recorded because all the patients go to hospital (Faculty of Tropical Medicine). However, there are no resources for active case detection at the Sena District Health Office. The Faculty of Tropical Medicine has done a serum survey of schoolchildren, identifying the presence of immunoglobulin G (IgG) antibodies. In schools, 80% of children had IgG present, which indicates that a high proportion of students were either immune, ill and asymptomatic, or had only mild symptoms (Faculty of Tropical Medicine).
In Thailand, health systems workers claim that incidences of dengue fever are currently underestimated because patients with mild or no symptoms do not go to hospital. This is an issue that needs to be addressed via mobilization of resources for active case detection. If the ratio of reported versus unreported cases was estimated then it would be possible to have a better estimate of dengue fever incidence. Interviewees stressed the difficulty of managing something that is not accurately measured.

### 4.3 Thresholds and Response

Our research found that there exists a threshold for response that is related to the number of reported dengue infections. If the number of cases for cold season (November to January) is high, as it was in 2008, then there is likely to be a problem in the following hot season (April to August). With more mosquitoes, there are more larvae and the number of dengue cases during the hot season will be high (Bureau of Vector-borne Diseases).

In Thailand, a dengue warning is issued when the rainy season starts. However, there are no specific thresholds for when a warning is issued (WHO CO Thailand). The dengue warning system was developed 6-7 years ago. Currently, the Thais are working to modify it for better detection (Faculty of Tropical Medicine).

In Thailand, the Surveillance Rapid Response Team (SRRT) deals with the response phase of all disease outbreaks including dengue fever (Bureau of Vector-borne Diseases). When there is as little as one case, the team is deployed to control spreading by spraying to reduce the number of infected mosquitoes within 100m. SRRT also works to mitigate outbreaks by control by emptying containers that may house larvae, through community education, and by distributing bed nets (Bureau of Vector-borne Diseases). Interview respondents at the Ayutthaya Provincial Office stressed that for every single dengue case they use all available resources during response (Ayutthaya Provincial Office). Said one respondent, “If one district has a greater number of cases, we increase the number of teams in that area. If more problems emerge, we mobilize other health workers. We have a very flexible system in place (Ayutthaya Provincial Office).”

In September of 2008, the Sena District Health Office was faced with an outbreak of 15 dengue cases. They responded by calling a war room meeting, and continued with monthly war room meetings as the outbreak trend continued to increase. In addition, they deployed extra response and mitigation teams to help affected regions, enlisted the help of volunteers, and engaged communities in health education. However, dengue incidences continued to increase. In response to this phenomenon one respondent said, “We did not understand
why it happened. We put all of our efforts in. We think there was not enough participation by the community (Sena District Health Office)."

When asked about whether or not they have a comprehensive response plan for an increase in dengue as a result of climate change the majority of respondents answered ‘no’. The Ayutthaya Provincial Office mentioned that competing priorities are holding back the development of a climate change response plan.

"Dengue has to be visible to gain public attention and the collaboration of health workers and the public” one respondent remarked. "Communication is not a problem. People are aware. But the difficulty is changing behaviour."

The Faculty of Tropical Medicine asserted that climate change response plans must be a Ministry policy. "The Ministry already prepares disaster management plans for climate change and national disaster management plans for other diseases,” one respondent said. "Now they recognize disasters like storms. They are aware of climate change. But for dengue they have no system.” According to interviewees at the Faculty of Tropical Medicine, policy makers at the Ministry of Health do not recognize climate change as important because the science of climate change and health is still in the research stage.

Because there are no response plans in place for increases in dengue fever as a result of climate change, we chose to ask questions about the policy and planning infrastructures in place for response to disasters and other diseases. Our interviews showed that members of the Thai health system are learning from disaster management strategies. The Faculty of Tropical Medicine held a table-top exercise after the tsunami. The Chatuchak District Health Office learned about response strategies from floods, fires, collapsed buildings, and bird flu epidemics. For example, after the SARS outbreak in Asia, the Bureau of Vector-borne Disease trained every district team, regional office and provincial team in response and mitigation. They also conducted risk simulations to better plan for outbreak response. "Simulations are held once a year,” said one respondent. "We have evaluated simulations for avian flu and plane crashes. We have to budget for this, for the funding of every province, and for capacity building.” Respondents stressed that ultimately, the quality of response and mitigation activity depends on the capacity of the local people.

As a result of climate change, not only is the number of dengue cases increasing, but the curve of dengue incidence may also be changing (Figure 3). If the Thai health system continues with business as usual, response mode will remain unable to decrease incidences of dengue over time. At some point the Thai health system will need to mount a large-scale response instead of increasing incrementally with each case.

There are several bottlenecks to triggering effective response that have been identified. These include community resilience, the pace of the decision-making process, and drug supply issues. Currently, the Thai health system can cope with
a 10–20% increase in cases. However, it would need to develop flexible resources to respond to an increase in cases of greater than 20%. It is not clear who will make the decision to respond. This may lead to significant communication issues during mitigation and response planning.

The Ministry of Health and local health offices are not always aware of the potential of climate change to dramatically transform the disease patterns of dengue fever. As we learned from the interviews, they have other priorities. “We can take care of the problem,” claims a respondent at the Faculty of Tropical Medicine. “It is a question of prioritisation if is a threat or not. It is not thought of as urgent.”

The Thai health system has protocols and simulations for heat waves and SARS, and so there are the systems in place, and the resources and capabilities to develop response plans. However, as can be seen from French heat wave in 2003 and the Brazil dengue outbreak in 2007, even the best health care systems can have high mortality rates if proper response planning is not in place. In the absence of response plans it takes longer for decisions to be made and for resources to reach the disaster areas. The Thai health system needs to translate the lessons learned from other disaster response situations to their management of dengue fever.
5. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

There are many peer-reviewed papers reflecting an awareness of the potential changes in dengue fever from climate change. However, there are no papers looking specifically at the preparedness of health systems and plans to respond to changes in dengue fever reasonably attributable to climate change. We developed a toolkit to assess the preparedness of health systems to changes in dengue fever from climate change.

Moreover, our Thailand case study illuminated some of the challenges, current strategies, and capacity of health care systems to respond to climate change related health threats. Thailand has a truly complex and sophisticated surveillance system for dengue fever. Overall, response to cases is a priority, and often times skilled response teams are deployed to the site of every case reported. However, with this reactive vector control strategy there is no system in place to identify long-term changes in dengue fever, and no response plan for changes as a result of a warmer climate.

In Thailand there is strong collaboration, innovation and enthusiasm at health centre level. However, there is an organizational issue in response because the system is so complex. There are good surveillance systems in place, but there are organizational issues in the field.

This paper is the first to explore how the Thai health system would cope with a sudden increase in dengue fever due to climate change. This is a significant initiative in encouraging awareness of this issue and the need for the Ministry of Health to create a response plan. Moreover, the case study provided a forum for the evaluation of the health system assessment toolkit. The toolkit can be applied to different countries as a Rapid Assessment Test. Gaps in health systems could be more easily identified, and guidelines could be formulated to aid preparedness to changes in dengue fever outbreaks.

This study was carried out as a collaborative effort between the Imperial College Consultants Ltd and the World Health Organization. It explored a new territory, followed robust methodology, developed a new toolkit and evaluated it with an exploratory case study in Bangkok. Systematic reviews were carried out to a high standard, following the Cochrane guidelines.

Ultimately, policy-makers need to become aware of the risk associated with climate change and dengue fever. Only then will they be able to prioritize the development of comprehensive response plans.

This study illuminates a number of potential research directions. Thai disease and weather data needs to be collected and analyzed in order to identify key trends in incidence and virulence. The results of these empirical studies can be used to further engage policy-makers. In addition, Thai health
care infrastructure will benefit greatly from further analysis of health system preparedness in the context of malaria and climate change. Robust case studies should be carried out to further validate the toolkit. Future research will help identify globally applicable guidelines for how to develop response plans for increases in dengue fever.

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