AIACC Final Reports

The Threat of Dengue Fever in the Caribbean: Impacts and Adaptation

A Final Report Submitted to Assessments of Impacts and Adaptations to Climate Change (AIACC), Project No. SIS 06

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A Final Report Submitted to Assessments of Impacts and Adaptations to Climate Change (AIACC), Project No. SIS 06

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About AIACC

Assessments of Impacts and Adaptations to Climate Change (AIACC) enhances capabilities in the developing world for responding to climate change by building scientific and technical capacity, advancing scientific knowledge, and linking scientific and policy communities. These activities are supporting the work of the United Nations Framework Convention on Climate Change (UNFCCC) by adding to the knowledge and expertise that are needed for national communications of parties to the Convention.

Twenty-four regional assessments have been conducted under AIACC in Africa, Asia, Latin America and small island states of the Caribbean, Indian and Pacific Oceans. The regional assessments include investigations of climate change risks and adaptation options for agriculture, grazing lands, water resources, ecological systems, biodiversity, coastal settlements, food security, livelihoods, and human health.

The regional assessments were executed over the period 2002-2005 by multidisciplinary, multi-institutional regional teams of investigators. The teams, selected through merit review of submitted proposals, were supported by the AIACC project with funding, technical assistance, mentoring and training. The network of AIACC regional teams also assisted each other through collaborations to share methods, data, climate change scenarios and expertise. More than 340 scientists, experts and students from 150 institutions in 50 developing and 12 developed countries participated in the project.

The findings, methods and recommendations of the regional assessments are documented in the *AIACC Final Reports* series, as well as in numerous peer-reviewed and other publications. This report is one report in the series.

AIACC, a project of the Global Environment Facility (GEF), is implemented by the United Nations Environment Programme (UNEP) and managed by the Global Change SysTem for Analysis, Research and Training (START) and the Third World Academy of Sciences (TWAS). The project concept and proposal was developed in collaboration with the Intergovernmental Panel on Climate Change (IPCC), which chairs the project steering committee. The primary funding for the project is provided by a grant from the GEF. In addition, AIACC receives funding from the Canadian International Development Agency, the U.S. Agency for International Development, the U.S. Environmental Protection Agency, and the Rockefeller Foundation. The developing country institutions that executed the regional assessments provided substantial in-kind support.

For more information about the AIACC project, and to obtain electronic copies of AIACC Final Reports and other AIACC publications, please visit our website at www.aiaccproject.org.

Summary Project Information

Regional Assessment Project Title and AIACC Project No.

The Threat of Dengue Fever in the Caribbean: Impacts and Adaptation (SIS 06)

Abstract

The impetus for this project was initiated by both the significant increases in the incidences of dengue fever in the Caribbean in the last 2 decades, as well as seeming and reported relationships between some peaks in dengue occurrence and increases in air temperature, some of which occurred in El Niño years. Climate Change scenarios in which temperature is projected to increase are therefore cause for serious concern. The starting point of the project was the construction of databases of past and present climate and dengue indicators for the Caribbean region. These databases were analyzed for linkages between climate and dengue by using standard statistical techniques (Retrospective study). A clear linkage and seasonality in the occurrence of dengue was found. A moving average temperature (MAT) index was found to be a good indicator for the potential of dengue occurrence. Linkages were also established by using real time data collected during the project (Prospective study) and 40 gallon drums were found to be major breeding habitats for the dengue vector. Vulnerability of a typical community to dengue was determined in a socio-economic study, and surveys were carried out to determine Knowledge, Attitude and Practices (KAP) in relationship to dengue and climate change. Projections of future climate for the Caribbean were downscaled statistically from global climate model outputs using SRES emission scenarios. All the results from the above formed the basis for an analysis of future impact of, and adaptation strategy for, climate change-induced dengue, including the use of an early warning system. Capacity building, including graduate training (7 students) and institutional building (Universities and Ministries), were an integral part of the project. Final workshops for stakeholders were held in Jamaica and Trinidad. Other outputs of the project include 3 papers in the final stages of preparation for major peer reviewed journals and the production of a monograph for operational use and for teaching purposes.

Administering Institution

The University of the West Indies, Mona, Kingston 7, Jamaica.

Participating Stakeholder Institutions

Ministry of Health, Kingston, Jamaica; National Meteorological Office of Jamaica, Kingston, Jamaica; Ministry of Health, Port of Spain, Trinidad and Tobago; Caribbean Epidemiology Centre, Port of Spain, Trinidad and Tobago; Ministry of Public Utilities and Environment, Port of Spain, Trinidad and Tobago.

Countries of Primary Focus

Twenty one member countries of the Caribbean Epidemiology Centre (CAREC): Anguilla, Antigua & Barbuda, Aruba, Bahamas, Barbados, Belize, Bermuda, British Virgin Islands, Cayman Islands, Dominica, Grenada, Guyana, Jamaica, Montserrat, Netherlands Antilles, St. Kitts & Nevis, St. Lucia, St. Vincent & the Grenadines, Suriname, Trinidad & Tobago, Turks & Caicos.

Case Study Areas

Barbados, Jamaica, Trinidad and Tobago, St. Kitts and Nevis, and St. Vincent and the Grenadines were targeted for more specific studies.

Systems and Sectors Studied

The study directly addressed human health. Indirectly it will affect tourism and the workplace

Groups Studied

The study encompassed all demographic groups, especially rural and urban poor in the region but samples were drawn from five specific islands namely, Jamaica, Trinidad and Tobago, Barbados, St. Kitts and Nevis and St. Vincent and the Grenadines.

Sources of Stress and Change

Temperature increases by as much as 2°C are expected in the Caribbean by the 2080's under A1 and B2 emission scenarios. Rainfall may decrease or increase slightly. Concomitantly, the extrinsic incubation period (period of incubation of parasite inside the vector or EIP) will shorten due to the higher temperature, leading to reduced development time within the vector and increased transmission rate of the disease. Increased temperatures are also expected to increase the number of blood meals and thus, the probability of dengue transmission to new hosts. Precipitation conditions are not as important as temperature increases, since wet conditions will provide more breeding habitats for the vector in open spaces in uncovered nonbiodegradable and other discarded containers or collectors, while in drier conditions water storage in containers, such as drums, will be the main breeding grounds.

Project Funding and In-kind Support

AIACC: US $218,250 GRANT; University of the West Indies, Mona: US $150,000 in-kind contribution; and Caribbean Epidemiology Centre, Trinidad: US $50,000 in-kind contribution.

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Executive Summary

Research problem

IPCC (1998), using a WHO source, indicated a likely alteration of the global distribution of dengue due to climate change, with 2.5 billion at risk in the tropics and subtropics. In fact dengue and dengue haemorrhagic fever (DHF) have emerged as two of the greatest vector-borne disease threats of modern times (Gubler and Clarke, 1995). In the Caribbean, since the last decade there has been a significant increase in dengue cases with increasing levels of severity of DHF and the local concurrent circulation of all 4 dengue fever serotypes, as illustrated in Figure ES 1.

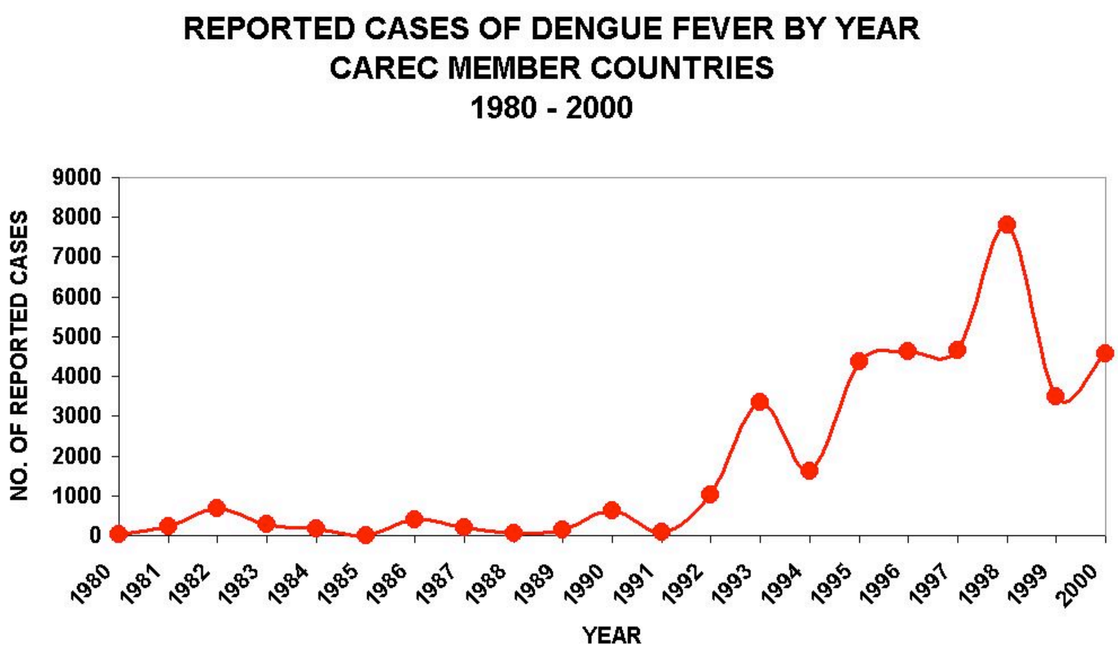

Fig. ES 1: Number of reported cases of dengue fever in CAREC countries from 1980 - 2000

Dengue haemorrhagic fever (DHF) and dengue shock syndrome (DSS) have been demonstrated as being the most vicious form of the disease in the Americas. In 1981, Cuba succumbed to the most serious outbreak of DHF/DSS ever recorded in the region – 344,203 dengue and DHF cases were reported including 10,312 severely ill patients resulting in 158 deaths (Pinheiro and Nelson, 1997). Venezuela suffered the second most serious outbreak in 1989-90, with 5,990 DHF cases and 70 deaths, and smaller epidemics have been reported in El Salvador in 1987-1988, Brazil, Colombia and Trinidad and Tobago in the 1990s. These outbreaks would have impacted on all sectors of the society including manufacturing, commerce and the tourism industry on which the region so heavily depends. In 1995, tourism accounted for 69% and 53% of GNP in Antigua and the Bahamas respectively, and more than 10% in most other islands in the Caribbean (IPCC, 1998). An outbreak of dengue can lead to losses in tourism since potential visitors may shy away from affected areas and even the region in general, since they may associate one affected island in the Caribbean with the entire region. The loss of productive time and the cost of treating the illness also make dengue epidemics a major cause of concern.

It is widely accepted that dengue epidemics result from a combination of factors including social, biological and environmental factors, such as social inequalities, poor sanitation, proliferation of water containers like discarded automobile tyres and other nonbiodegradable containers. Climate factors also play a role. On the epidemiology side, Hales et al., (1996) have linked the transmission of dengue fever to temperature. The extrinsic incubation period (EIP) shortens at higher temperatures, and Focks et al (1995) indicated that dengue type 2 has an EIP of 12 days at 30° C but only 7 days at 32-35° C. Thus transmission rate could increase with temperature. Koopman et al., (1991) found that decreasing the incubation period by 5 days can lead to a threefold higher transmission rate of dengue. Also, moderately high temperatures can hasten the larval stage, leading to smaller mosquitoes, which will require more frequent blood meals, and temperature increases additionally will enhance metabolism. Thus higher temperatures may increase the amount of feeding within the gonotropic cycle (McDonald, 1957), and thus increase the probability of dengue transmission to new hosts.

On the climate side, research has also shown a link between dengue transmission and climatic variability associated with the El Niño Southern Oscillation phenomenon. Hales et al (1996) also found an upsurge of dengue fever in the islands of the south Pacific to be associated with ENSO events. Poveda et al (2000) showed that, in time series displays, most peaks in the number of dengue cases in Colombia (including the Caribbean coast) and of DHF in Antioquia (northwestern Colombia) corresponded to El Niño +1 years (the year following the winter peak in equatorial Pacific sea surface temperature). They suggested that temperature increases and available stagnant waters may have accounted for the upsurges. This is because El Niño causes prolonged drought in Colombia and many rural towns require the storage of water in cans and tanks, thus creating more breeding sites and favoring the spread of dengue in the country.

Figure ES.1 shows that peaks in the incidence of dengue in the Caribbean occurred in the El Niño years 1982 and 1986 and in the year after the 1997 El Niño, the El Niño + 1 year of 1998. The year 1992, in which the incidence is higher relative to previous years, is also an El Niño + 1 year, and this El Niño was a protracted one with above normal temperatures extending into 1993. It can also be argued that these occurrences of dengue are related to climate. Taylor (1999) and Chen and Taylor (2001) showed that rainfall and temperature increase during May to July in the El Niño + 1 year in the Caribbean. This could lead to increased mosquito breeding in the Niño + 1 year if the rainfall is just sufficient to maintain isolated pools on the ground or in discarded containers (a common situation in the Caribbean) and the temperatures remain high enough for increased transmission of the disease.

Finally, information provided by Santer (2001), show that a mean temperature increase of up to 2ºC was projected in Caribbean temperature after 70 years of simulation with CO_2 doubling. On the other hand, not much change in precipitation is expected. Based on research to date, these increases in temperature could lead to a substantial increase in the incidence of dengue. Furthermore the expected modulation of temperature by future El Niño events will further enhance this increase periodically. It is argued then that because of projected temperature increases and known El Niño induced temperature increases, with rainfall climatology remaining roughly the same, increased vector abundance and dengue fever will pose a serious threat in the future and that adaptation strategies must be developed to counteract this threat.

Overall aim

The overall aim of this project therefore was to establish the relationship between the incidence of dengue and climate, and to lay a framework for developing adaptation strategies, keeping in mind that the ability to predict climate, especially the onset of El Niño, is constantly improving.

Primary objectives

The primary objectives of this project were:

1. To determine the extent of the association between climate and the incidence of dengue across the Caribbean region and the dominance of this linkage in comparison to other linkages.
2. To identify and evaluate adaptive options to ameliorate the impact of climate on dengue.
3. To use the knowledge gained above to determine future impacts and adaptation based on global change scenarios of the future.
4. To make the knowledge gained accessible and useful to decision-makers.

The approach

The approach to assess impact of, vulnerability and adaptation to, climate change and to disseminate knowledge involved nine main tasks:

1. Development of climate and epidemiology databases
2. Analyzing the relationship between climate and epidemiological patterns of dengue fever and its vector in (i) a retrospective study and (ii) a prospective study.
3. Obtaining downscaled future projections of climate for the Caribbean from coupled atmosphere ocean general circulation model (AOGCM) outputs using the Special Report on Emissions Scenarios (SRES) of the U.N. Intergovernmental Panel on Climate Change (IPCC).
4. Executing a socio-economic study to determine the vulnerability of a typical community to dengue fever.
5. Conducting of a Knowledge, Attitude and Practices (KAP) survey to determine to determine the levels of understanding of climate change and public health issues relating to dengue fever, and to ascertain whether respondents would be willing to undertake adaptation strategies for dengue fever prevention.
6. Designing a pilot project for Jamaica to implement an integrated system capable of monitoring vector and disease, forecasting climate and dengue incidence, and undertaking diagnostics and adaptation applications for the near term (5 years or less).
7. Determining the type of containers most effective in producing the vector of the disease (mosquitoes) in order to determine the containers needed to be targeted in any vector eradication programme (This activity was supported by supplementary funds sourced by AIACC).
8. Analyzing adaptation strategies for dengue induced by future climate change using climate projections, socio-economic information and knowledge gathered from the study.
9. Engaging stakeholders by conducting workshops and disseminating reports.

Scientific findings

The climate and epidemiology data bases were successfully developed, although there were problems with obtaining climate data and with the quality and reporting of epidemiology data. These problems, except in the case of the Barbados epidemiology data, were minor and did not affect the findings.

A retrospective study was conducted to determine the nature and extent of the association between climate and the incidence of dengue across the Caribbean, and to quantify the association in terms of a measurable parameter such as temperature, and develop a procedure to predict the potential for the onset of dengue. The results of the study revealed that there was a well defined seasonality associated with dengue epidemics in the Caribbean region. There was an association of the disease with climate, especially through temperature and during El Niño episodes (El Niño and El Niño+1 events). This association was more pronounced in the Trinidad and Tobago data. Indices linked to temperature (early temperature peak, lapse time to disease onset, average temperature at disease onset, and the Moving Average of the Temperature (MAT) – roughly the average temperature to date from the start of the year) helped to predict the potential for the onset of dengue. The average MAT values for the different countries at onset could be used as thresholds for onset as the MAT values in different years approached the average MAT values of the respective countries at time of dengue onset. There were a few years in which the MAT value increased at a much greater rate than normal, reaching the average value before the dengue onset, but in these years the dengue onset also came much earlier. Likewise in the years in which the MAT value increased at a much slower rate, the dengue onset occurred much later.

A prospective study was also carried out to determine the relationship between climate and the dengue vector and disease in selected Caribbean countries. The research was initiated in early 2003. At first, four countries were selected as sites in which these studies were to be conducted, but soon after experiencing trouble with the Barbados' data another country, St Vincent and the Grenadines, was added to the group which was then Trinidad and Tobago, Jamaica, Barbados, St. Kitts and Nevis and St Vincent and the Grenadines.

The data collected were primarily monthly reports of dengue cases, Breteau indices and House indices (See box 1 below) of the dengue vector, Ae aegypti, in the designated study areas, and monthly climate data obtained from the local meteorological office for the study areas. A minimum of 100 residences were examined per month for a 12 month period. Results of this study confirmed that there is "a dengue season" in Trinidad which coincides with the rainy season, and established that temperature alone did not appear to be associated with an increase in dengue occurrence. Thus while temperature can be used to determine the potential for the onset of dengue, it could not of itself predict an occurrence. The study also showed that the Breteau index is a good indicator for the potential of dengue occurrence in a dengue endemic environment.

Box 1. Definitions

- The Household Index (HI) is defined as the total number of homes found to be positive for Ae aegypti breeding per 100 homes inspected.
- The Breteau Index (BI) is the defined as the total number of Ae aegypti - positive containers detected per 100 homes inspected.

Because of the economic constraints of the project, the socio-economic component of the project focused on the island of Jamaica only. Jamaica has the most thorough socio-economic data set of the islands, and yet is similar to most of the other islands in socio- economic terms, having a common history. The study focused on three communities in the parish of St. James. It adopted a mixed methodology, consisting of expert interviews and a questionnaire survey, backed up by secondary data, to assess the capacity of the country to respond to any crisis, as well as its capacity to respond to the challenges posed by outbreaks of dengue fever (specific adaptive capacity). The results of the study revealed that Jamaica's inability to achieve any real economic growth since the 1970's has affected its ability to respond to any crisis including a dengue epidemic. Interviews with experts from the Ministry of Health revealed that resource problem limits the ability of the organization to respond adequately to present conditions regarding dengue – routine vector surveillance and control programmes have ceased and public education programmes are also a victim of financial constraint. Thus a decision was made not to spend scarce resources on "lower priority health problems" (Apart from 1995 and 1998, Jamaica has not had a significant outbreak of DF since the great epidemic of 1977, in contrast to the situation in Trinidad and Tobago.) Interviews conducted with other public sector agencies revealed that the threat of sea level rise was their foremost concern. The study also revealed that the poor were most vulnerable to dengue fever. Many of these persons lived in informal settlements in both rural and urban communities which possessed conditions which are conducive to the proliferation of the dengue vector and virus. Many of these poor households were headed by females, many of whom were unemployed, had no skills and displayed a high level of ignorance regarding the disease and its transmission.

Knowledge, Attitude and Practices (KAP) surveys on the issues of climate change and public health were also carried out in four Caribbean countries, namely Trinidad and Tobago, Jamaica and St. Kitts and Nevis. The objective of these studies was to determine the levels of understanding of the issues of climate change and public health by the respondents and to ascertain whether they would be willing to incorporate adaptive strategies for dengue fever prevention. The study concluded that despite the fact that knowledge and attitudes did not always coincide with practices of using environmental sanitation for dengue fever prevention, it seemed that respondents could be persuaded to use such strategies. There was also a need for promoting the usefulness of community involvement, and for demonstrating the efficacy of using climate change information in dengue fever, and possibly other disease, prevention

The pupae survey project revealed that 40 gallon drums commonly used for outside water storage in the Caribbean was the main source for the production of mosquitoes.

To generate the future climate expected in Caribbean, outputs from coupled Atmospheric Ocean Global Climate models (AOGCM) from various climate change centres were downscaled statistically. The AOGCM's runs used were those using A1 and B2 SRES emission scenarios. Time slices for the 2020's, 2050's and 2080's were processed by Canadian Climate Impacts Scenarios (www.cics.uvic.ca/scenarios/index.cgi?Scenarios) for use in the statistical downscaling model, SDSM, developed by Wilby et al (2002). The results indicate that the temperature of the Caribbean is likely to increase by around 2º C by 2080's. A rise of 2º C is expected to lead to a 3-fold increase in transmission of dengue fever (Focks et al, 1995 and Koopman et al, 1991). Climate change therefore poses a definite health threat in the Caribbean. Compared to the results for temperature, the results for precipitation were very uncertain. There could be a decrease or increase in precipitation, and more investigation is needed, especially with the use of regional climate models.

An early warning system to predict the potential for the onset of dengue was developed. It relies mainly on the rate of increase of the MAT index, with a greater rate of increase indicating early potential for dengue. Since temperature data are collected on a daily basis, it is easy to obtain the MAT index. Once the MAT index approaches a threshold value, more costly surveillance for the disease can be put into place. The system is therefore cost effective.

Strategies for adaptation (prevention), including the early warning system, were developed based on the above results keeping in mind that the study revealed that there was already an adaptation deficit in dealing with current prevention of dengue. Strategies were developed by means of (i) the identification and classification of current adaptive strategies through collaboration with Health Ministries, (ii) the use of a matrix analysis to examine the characteristics and constraints of present adaptive practices and possible future practices, and (iii) the identification via expert judgment of a limited best set of practices, for recommendation to government officials and other stakeholders. For future impacts a 2ºC in temperature was assumed, which would lead to a 3-fold increase in dengue transmission.

Capacity building outcomes and remaining needs

Five staff member of The University of the West Indies, Mona, Jamaica and St. Augustine, two from the PAHO/WHO Caribbean Epidemiology Centre, Trinidad, and several from the Ministries of Health, Jamaica and Trinidad and Tobago were involved in the project. One of the achievements of this project is that the researchers at these institutions have learnt the interdisciplinary techniques of studying climate change impacts on dengue occurrence and developing adaptation strategies using both climate and epidemiology data. There is also ample evidence that, now that the project has been completed, collaborative research on climate change between the two institutions will continue, by self financing means and otherwise, since the institutions are dedicated to research. Collaboration will be especially important when new climate change scenarios become available and new disease associations and trends emerge.

In addition, a major component of the project was the training of 7 graduate students, who have been encouraged to continue their career paths in fields where their acquired skills can be used directly or indirectly in governmental, environmental, educational and/or research institutions. For example, with seasonal to interannual predictions of climate and applications of such predictions becoming more recognized and used in planning, meteorological services in the region will be looking for persons with skills in database building and statistical downscaling. Students who worked in this project will be able to fulfill this demand. Finding such employment for the students is the most pressing remaining need.

National communications, science-policy linkages and stakeholder engagement

The results of project SIS06 will definitely be included in Jamaica's National Communication, and efforts are being made to have it included in the Communication of other islands. This project has laid the foundation for providing the basic inputs for decision making. It is assumed that collaborative research on climate change will still continue now that the project is over, so that there will always exist a body of researchers whose presence will be felt in climate change issues by enlightening and enlivening discussions on the subject, and who can be called upon to provide the necessary input to decision making. These researchers will provide the expertise in determining the level of reliability or uncertainty of the climate change projection, the severity and spatial extent of the threat, the adaptation strategies to be employed and the projected outcome. Decisions makers must consider all these inputs as well as others, such as those related to economic considerations, in arriving at decisions on adaptation strategies.

To hasten the process and to explain the relevance of the project to decision makers, two workshops were held in Trinidad and Jamaica at the end of the project to outline the results of the project and their potential for decision making. The results were well received at both workshops, and the Director of Disease Prevention and Control Division of the Ministry of Health in Jamaica has indicated that she would like to set up a simple form of the proposed early warning system, and meetings are to be arranged to discuss the matter.

Further the results of the project are to be disseminated to all stakeholders, including those who attended the workshops in the form of (i) CD's of the workshop presentations and (ii) a monograph of the results of the project which can be used for classroom and workshop purposes.

Policy implications and future directions

The project has demonstrated a linkage between climate and dengue occurrence and has made recommendation for adaptive strategies, including an early warning system. It is for the main stakeholders, the Ministries of Health in the region, to evaluate and, if necessary, implement these recommendations. In the meanwhile, there is need for research to investigate the impact of climate on other diseases such as respiratory diseases (e.g. asthma), as well as food- and water-borne diseases.

1 Introduction

1.1 Research Problem

The impetus for this project was initiated by (i) recent increases in the incidence of dengue fever in the Caribbean and (ii) a seeming relationship between some peaks in dengue occurrence and increases in air temperature, some of which occurred in El Niño years. Research has revealed that the occurrence of dengue is sensitive to factors such as temperature increase and rainfall, and scenarios in which temperature is projected to increase with a possible change in the hydrological cycle are therefore cause for serious concern

1.1.1 Dengue in the Caribbean

In the Caribbean in recent times, from 1991 onward, there has been significant increases in dengue cases with increasing levels of severity of DHF and the local concurrent circulation of all 4 dengue fever serotypes, as illustrated in Figure 1 ES above. Data indicate that prior to 1991 there was only occasional occurrence of the disease in the 21 CAREC Member Countries (CMCs). Since then however, the overall Caribbean situation has been one of continuing endemicity of DF, despite the fact there have been fluctuations with declines in 1999 and 2003, and peaks of transmission in 1998 and 2002. The countries which were most affected were the Southern Caribbean countries of Suriname, Guyana, Trinidad and Tobago, Grenada and Barbados. Not reported on here, but also affected by the DF scourge were the French Departments of French Guiana, Guadeloupe and Martinique. Northern CMCs such as Jamaica and Bahamas, despite the presence of significant vector abundance, somehow managed to be only occasionally affected by epidemics of the DF virus. Because of the large number of cases reported from Trinidad and Tobago, the national DF data were a virtual replica of the Caribbean-wide situation, except for the absence of a peak of transmission in 1999.

Table 1.1 shows the distribution of dengue fever peaks among ENSO phases in 5 selected CMCs. It shows that for the period (1980-2002), out of a total of 8 DF peaks of transmission 7 occurred in El Niño+1 years in the entire Caribbean, and 6 in Trinidad and Tobago. Barbados experience 5 peaks in El Niño+1 years out of 6, Jamaica 4 of 5 and Belize 3 of 4. Only in one year was there a La Nina associated outbreak in Belize.

REGION	TOTAL	El Niño & +1	La Nina	Neutral
Caribbean	8	7	-	1
T & T	8	6	-	2
Barbados	6	5	-	1
Jamaica	5	4	-	1
Belize	4	3	1	

Table 1.1: Distribution of dengue peaks among the ENSO phases in selected countries from 1980 - 2002

Figure 1.1 shows that, to a large extent, Trinidad and Tobago was one of the largest contributors to the CMCs Caribbean DF endemicity when compared to the total Caribbean in Figure ES1. Fig. 1.1.2 shows the Barbados situation with a significant occurrence of DF in 1995, and with some fluctuations, DF has remained endemic on the island since then; since 1999, the figures of reported cases have remained fairly steady at about 700 cases per annum.

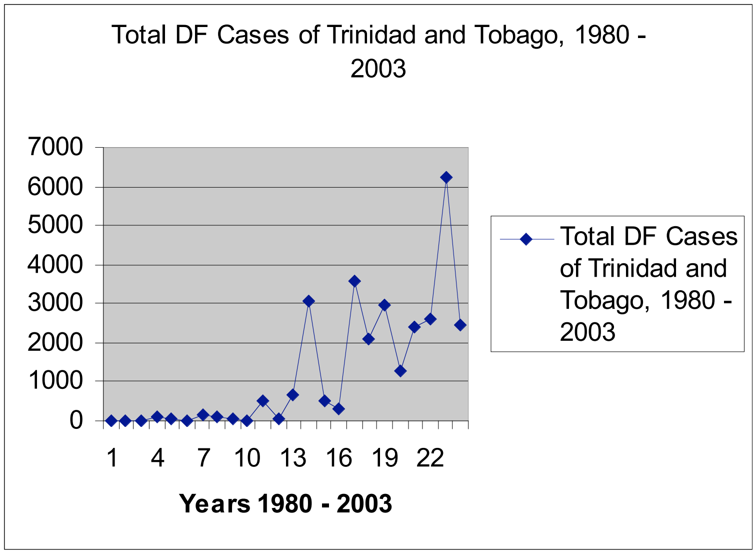

Fig. 1.1: Pattern of dengue fever cases in Trinidad and Tobago, 1980-2003

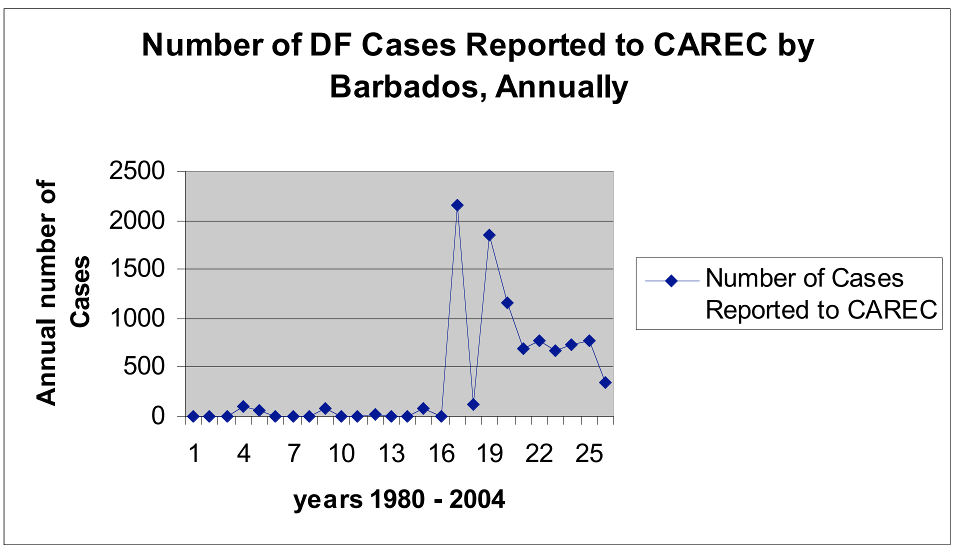

Fig. 1.2: Dengue fever occurrence in Barbados, 1980-2004

Figure 1.3 shows the epidemic situation of DF in Jamaica as opposed to the endemic situation in the southern Caribbean. Despite significant epidemics in 1995 and 1998 and persisting large vector abundance, DF has not been prevalent in the other years. There has however been small numbers of DF in all years, largely detected in the paediatric fever/rash survey for measles.

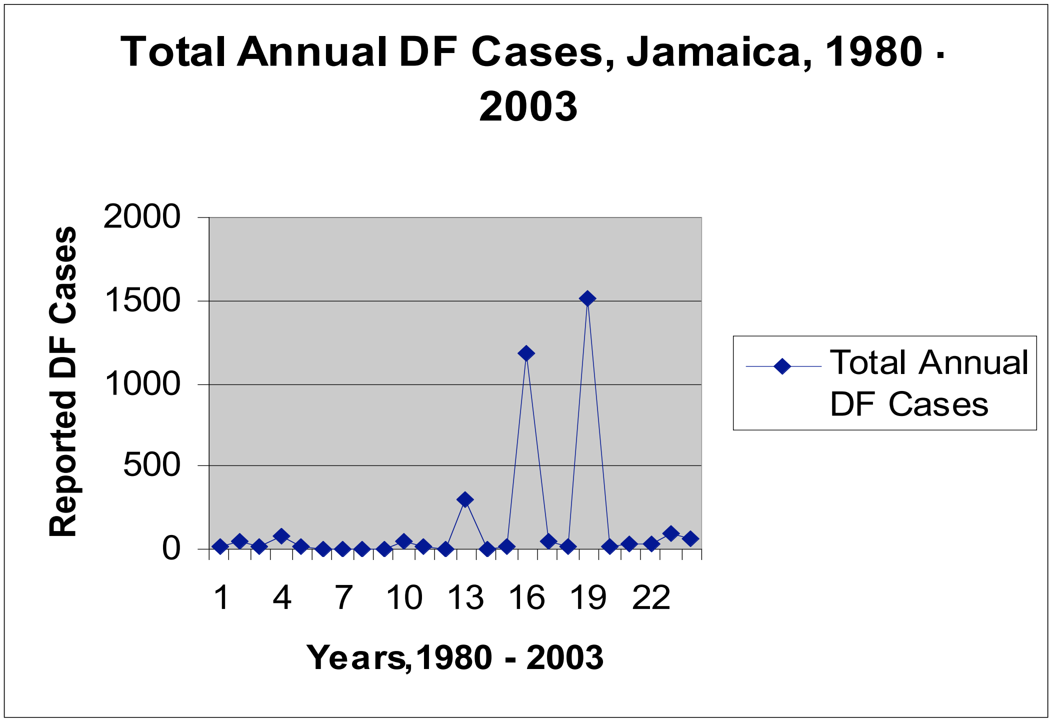

Fig. 1.3: Dengue fever occurrence in Jamaica, 1980 -2004

Figures 1.4 and 1.5 show epidemic situations in St Vincent and the Grenadines (SVG) and in St Kitts/Nevis (SKV) respectively. In SVG, there were hardly any epidemics prior to 1995, but since then epidemics occurred in 1996, 1998 and 2002. In a similar manner, in the smaller SKN, there were no epidemics of significance in any years other than in 2001.

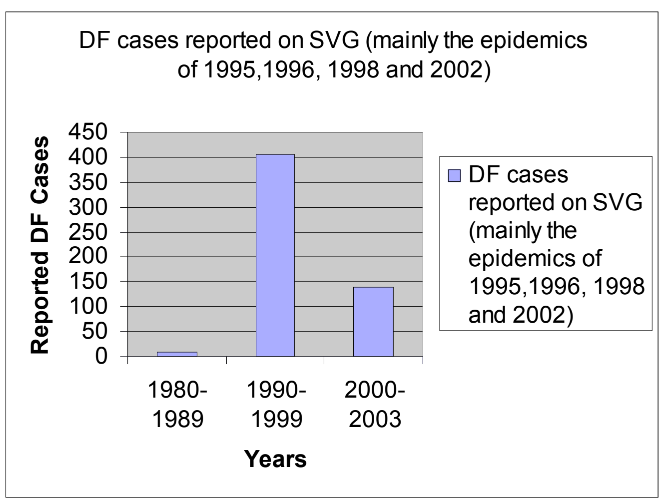

Fig. 1.4: The Dengue fever situation in St Vincent and the Grenadines, 1980-2003

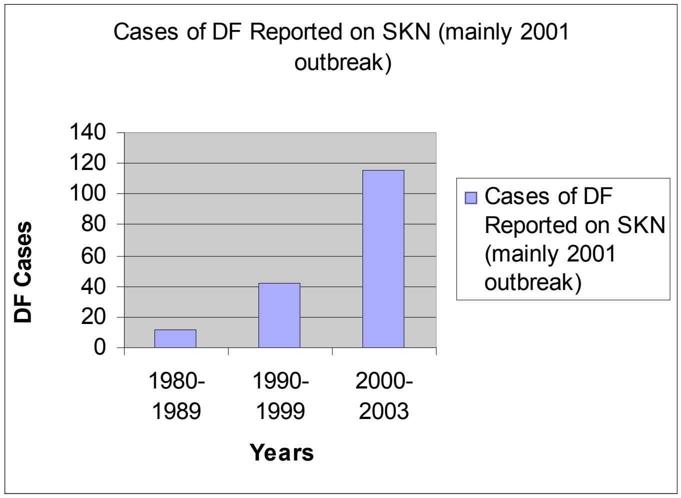

Fig. 1.5: Dengue fever in St Kitts/Nevis, 1980 – 2003

The DF serotypes in circulation are of significance. An example is the Trinidad and Tobago situation (Table 1.2). Prior to 1996, DF types 1 & 2 were common in the region. From 1997 to 2001, there was Type 2 only, then in 2002, Type 3 was introduced, and remains to 2004 to be the major cause of DF in CMCs .

Year	No. of Cases	Main DF Serotype in circulation
1996	3588	1
1997	2081	2
1998	2984	2
1999	1199	2
2000	2238	2
2001	2417	2
2002	6314	3 & 2
2003	2326	3 & 2
2004	600	3

Table 1.2: Dengue fever cases and main DF virus type in circulation in Trinidad and Tobago in 1996 - 2003

There was an accompanying increase in the prevalence of DF cases with the occurrence of new serotypes. For example, Trinidad and Tobago showed a significant increase in cases in 2002, the year of arrival of DF 3 in the region (Fig.1.6). This was probably related to high levels of sensitivity of the population to DF 3, which had been unknown in the region in recent times. It is known that absence of previous exposure is one of the risk factors for DF transmission.

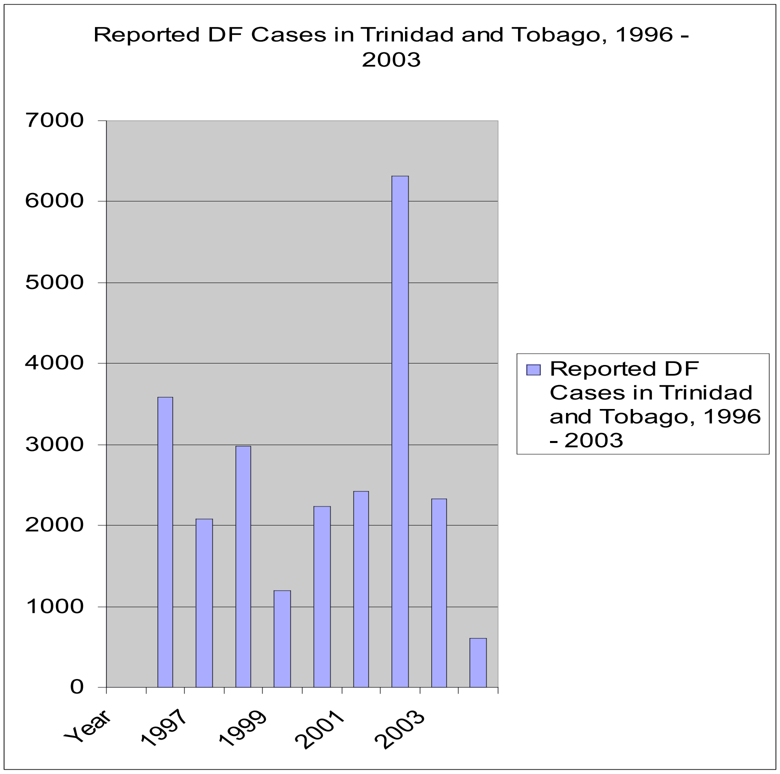

Fig. 1.6: Reported DF cases in Trinidad and Tobago, 1996-2003

Dengue haemorrhagic fever (DHF) and dengue shock syndrome (DSS) have been demonstrated as being the most vicious form of the disease in the Americas. In 1981, Cuba succumbed to the most serious outbreak of DHF/DSS ever recorded in the region – 344,203 dengue and DHF cases were reported including 10,312 severely ill patients resulting in 158 deaths (Pinheiro and Nelson,1997). Venezuela suffered the second most serious outbreak in 1989-90, with 5,990 DHF cases and 70 deaths, and smaller epidemics have been reported in El Salvador, in 1987-1988, Brazil, Colombia and Trinidad and Tobago in the 1990s.

Besides the risk to life, dengue fever has no doubt resulted in adverse impact on all sectors of the society from manufacturing and commerce to tourism. Besides the loss of productive time and the cost of treating the illness, an outbreak of dengue can lead to losses in tourism since potential visitors may shy away from affected areas, and even the whole region in general, since they may associate one affected island in the Caribbean with the entire region. In 1995, tourism accounted for 69 per cent and 53 per cent of GNP in Antigua and the Bahamas respectively, and more than 10 per cent in most other islands in the Caribbean (IPCC, 1998).

1.1.2 Association between dengue and climate

Although dengue outbreak is multifactoral, involving social, biological and environmental factors, such as poor sanitation, proliferation of water containers like discarded automobile tyres and other nonbiodegradable containers, social inequalities, etc., climate factors also play a role. Hales et al (1996) have linked the transmission of dengue fever to temperature. The extrinsic incubation period (EIP) of the viruses shortens at higher temperatures and Focks et al (1995) indicated that dengue type 2 has an EIP of 12 days at 30° C but only 7 days at 32-35° C. Thus transmission rate could increase with temperature and Koopman et al (1991) found that decreasing the incubation period by 5 days can lead to a threefold higher transmission rate of dengue. Also, moderately high temperatures can hasten the larval stage, leading to smaller mosquitoes, which will require more frequent blood meals, and temperature increases additionally will enhance metabolism. Thus higher temperatures may increase the amount of feeding within the gonotropic cycle (McDonald, 1957 in a study of malaria), and thus increase the probability of dengue transmission to new hosts.

It is not surprising therefore that dengue fever has been associated with seasonal and inter-annual changes in climate. Hales et al (1996) also found an upsurge of dengue fever in the islands of the south Pacific to be associated with ENSO events. Poveda et al (2000) showed that, in time series displays, most peaks in the number of dengue cases in Colombia (including the Caribbean coast) and of DHF in Antioquia (northwestern Colombia) corresponded to El Niño +1 years (the year following the winter peak in equatorial Pacific sea surface temperature). They suggested that temperature increases and available stagnant waters may have accounted for the upsurges. This is because El Niño causes prolonged drought in Colombia and many rural towns require the storage of water in cans and tanks, thus creating more breeding sites and favoring the spread of dengue in the country.

1.1.3 Dengue and climate in the Caribbean

It can be seen in Figure ES.1 that peaks in the incidence of dengue in the Caribbean occurred in the El Niño years 1982 and 1986, and in the El Niño + 1 year 1998. The year1992, in which the incidence is higher relative to previous years, is also an El Niño + 1 year, and this El Niño was a protracted one with above normal temperatures extending into 1993. Thus there may well be an El Niño signal embedded in the Caribbean data, which needs to be established. Taylor (1999) showed that the El Niño years in the Caribbean are associated with drier than normal conditions in the latter half of the year, leading to the need for domestic storage of water. This decrease in rainfall has also been reported by others, including Ropelewski and Halpart (1996). In addition, the air temperature increases during El Niño conditions (Malmgren et al, 1998). These are conditions suitable for increases in the incidence of dengue, as suggested by Poveda et al (2000). Taylor (1999) and Chen and Taylor (2001) showed that temperature and rainfall increase during May to July in the El Niño + 1 year in the Caribbean. This could lead to increased mosquito breeding and disease transmission in El Niño + 1 years if the rainfall is just sufficient to maintain isolated pools on the ground or in discarded containers (a common situation in the Caribbean). The sharp swing in the incidence of dengue from 1991 onward (Figure ES.1) may be related to increases in minimum temperatures, although socio-economic causes must not be overlooked. IPCC (1998), for instance, reported that the Caribbean islands experienced an increase in mean annual temperature of more than 0.5○ C during the period 1900-1955.

Because of these connections, future or long term changes in climate are a source of concern. Information provided by Santer (2001) on the assessment of model skills and uncertainties in scenarios of future climate change in the Caribbean showed that, from averaging the results of CMIP2 model runs, a mean temperature increase of up to 2ºC is projected in Caribbean temperature after 70 years of simulation with CO2 doubling. On the other hand, not much change in precipitation was expected. Based on research to date, these increases in temperature could lead to a substantial increase in the incidence of dengue. Furthermore the expected modulation of temperature by future El Niño events will further enhance this increase periodically. The change in the El Niño phenomenon itself in response to climate change is not yet clear, but Timmermann et al (1999) have reported an increase in El Niño frequency in a climate model forced by future greenhouse warming. It has been argued then that because of projected temperature increases and known El Niño induced temperature increases, with rainfall climatology remaining roughly the same, increased vector abundance and dengue fever will pose a serious threat in the future and that adaptation strategies must be developed to counteract this threat.

The aim of this project therefore was to firmly establish the relationship between the incidence of dengue and climate in the Caribbean region and to lay a framework for developing adaptation strategies, bearing in mind that the ability to predict climate, especially the onset of El Niño, is constantly improving. In so doing we will look at the effects of both seasonal and inter-annual changes in climate, referred to as climate variability, and long term change in climate, referred to as climate change.

1.2 Research Objectives

The primary objectives of this project were to:

1. Determine the extent of the association between climate and the incidence of dengue across the Caribbean region and the dominance of this linkage in comparison to other linkages.
2. Determine impacts and vulnerability due to dengue induced by climate (climate variability)
3. Identify and evaluate adaptive options to prevent and ameliorate impacts and vulnerability associated with climate variability.
4. Use the knowledge gained above to determine anticipated impacts and adaptation based on global change scenarios of future climate (climate change);
5. Make the knowledge gained accessible and useful to decision makers.

The project had a duration of 3 years from 2001-2004 and all 21 Caribbean Epidemiology Centre (CAREC) Member Countries (CMCs) were included for general observations, but 4 countries - Jamaica, Barbados, Trinidad and Tobago and St. Kitts – were targeted for specific study. These countries are of varying size and possess varying levels of complexity of ecology.

The project has thus addressed steps to overcome impediment to responses to climate change in small island states of the Caribbean cited by IPCC (1998) by

a. making projections of temperature and rainfall more definitive
b. making statements on ENSO impacts less ambiguous
c. making vulnerability assessment methodologies less 'poorly harmonized with local conditions'

It has facilitated adaptation to climate change in the Caribbean by providing

a. a framework for regional cooperation and coordination
b. a framework for 'owning' the issue of climate change and variability
c. a 'strategy for capacity building, awareness-raising and technical capacity enhancement'
d. a better understanding of climate change on which to base plan and action.

It is quite evident that no other work of this magnitude and depth has been undertaken in the Caribbean. The Caribbean Planning for Adaptation to Climate Change (CPAAC), for instance has largely been concerned with coastal zone impacts.

1.3 Research Components

The research components were:

a. Development of climate and epidemiology databases
b. Retrospective study of relationship between climate and dengue fever
c. Prospective study of relationship between climate and dengue fever and the disease vector
d. Socio-economic study of the vulnerability of a typical community to the disease
e. Kap survey to determine knowledge, attitude and practices regarding climate change, its association with dengue and disease prevention
f. Generation of future climate change scenarios
g. Developing strategies, including an early warning system, for prevention or
h. Adaptation in the case of both climate variability and climate change induced dengue
i. Workshops for stakeholders

After the start of the project two more components were added (i) a pupal survey to determine the type of containers which were most effective in producing the disease vector with a view of targeting these containers in vector eradication programmes, (ii) two laboratory studies to confirm the effects of temperature on a) vector competence and b) insecticide susceptibility of the dengue vector, Aedes aegypti.

1.3.1 Databases

The starting point of the investigation was the construction of both climatic and epidemiological databases, (details of these will be given later in the report). Using statistical techniques, the databases were analyzed for linkages between climate and dengue.

1.3.2 Retrospective and prospective study

The purpose of the retrospective study was to determine the characteristics of the epidemiological patterns of dengue fever in relation to climate using past data obtained from the climate and epidemiology databases. The aim of the prospective studies was to examine the occurrence of DF and population features of the vector with varying climatic features such as temperature and precipitation using data collected during the project. These studies formed the basis of determining the impact of climate on dengue fever.

1.3.3 Socio-economic study and KAP survey.

Because of economic constraints of the project the socio-economic study focused on the island of Jamaica only. Jamaica had the most thorough socio-economic data set of the islands, and yet was similar to most of the other islands in socio-economic terms, having a common history. The objective of the socio-economic analysis was to analyze the vulnerability of communities to climate change induced dengue fever. The study adopted a mixed methodology consisting of expert interviews and a questionnaire survey backed up by secondary data to assess the capacity of the country to respond to any crisis as well as its capacity to respond to the challenges posed by outbreaks of dengue fever (specific adaptive capacity). Secondary data for the socio-economic analysis were drawn from the Jamaica Survey of Living Conditions, an annual household survey, and from the national accounts. A survey of knowledge, attitude and practices (KAP) was also conducted to determine the levels of understanding of the issues of climate change and public health by populations of St Kitts and Nevis, Trinidad and Tobago and Jamaica to ascertain whether respondents would be willing to incorporate these values into strategies for dengue fever (DF) prevention. Using a cluster sampling system, representative samples of communities of St Kitts and Nevis (227), Trinidad and Tobago (650) and Jamaica (300) were surveyed for responses to a questionnaire document with questions on the impact of climate change on health, the physical environment, respondents' willingness to utilize climate change issues to predict and adapt to climate change for dengue fever prevention. Data were analyzed by SPSS and X sq. Together with the impact studies, these investigations guided the formation of adaptation strategies.

1.3.4 Generating future climate change scenarios

Statistical downscaling techniques were used to project climate change scenarios of the islands using outputs from coupled atmospheric ocean global climate models (AOGCM's) that use SRES emission scenarios as inputs. This was necessary since the outputs from the AOGCM's were course in resolution, giving results for the entire region rather than for individual islands. Statistical downscaling, which related the climate of the individual islands to the gross parameters of the AGCM's, was a means of achieving finer resolutions for the islands. On the assumption that the determined relationships between climate and dengue will hold in the future, the statistically downscaled scenarios for the islands were used to determine future impacts.

1.3.5 Developing strategies of adaptation

The adaptation strategies were largely dependent on the assessments of impact based on the retrospective and prospective studies, and of vulnerability and present state of preparedness based on socio-economic assessment and KAP survey. Strategies were determined in the light of not only future climate (climate change), but also of present climate (climate variability). An early warning system was designed for the implementation of an integrated system capable of monitoring vector and disease, of forecasting climate and dengue incidence, of undertaking diagnostics and adaptation applications for the near term. Its purpose was to provide a model or prototype for long term adaptation. The early warning system can therefore be viewed as the first recommended step in the response for adaptation to climate change.

1.3.6 Workshop for stakeholders and other components

To inform and engage stakeholders workshops were planned for Ministry of Health officials, Meteorological Office officials and others in Jamaica and Trinidad. Since capacity building was a major component of the project, graduate students were engaged in most of the activities and special training sessions were held for held for some of them.

1.3.7 Components added after the start of the project

The following components were added after the start of the project. Since they are ongoing they will not be discussed in detail in the following chapters. However brief descriptions of these components are given immediately below:

1.3.7.1 Pupal survey and transmission thresholds

The overall aim of this component of the project was to:

1. Determining the more productive breeding containers responsible for transmission of dengue by means of a pupal/demographic survey of important breeding sites in Jamaica, and thereby establishing a basis for target control measures for transmission of dengue
2. Establishing transmission threshold for dengue in Jamaica

To date, pupal /demographic survey have been conducted in four parishes across the island, namely, St. James in the West, Portland in the East, St. Catherine in the South and St. Ann in the North. The survey was done for a wet season and a dry season. A total of 1200 houses were inspected.

For the survey, one community was selected from each parish listed above. Communities selected were based on knowledge of where there was a possibility of water storage due to inadequate water supplies. Within the selected communities, houses to be inspected were selected using systematic sampling. Inspection was conducted indoors as well as outdoors. Data collected were:

- Number of person in household
- Size of property (where known)
- Type of container found (place, size and quantity)
- Number of pupae found in each container type
- Number of larvae (this was estimated)
- Container manually or rain filled

The next stage of this project is to analyse the data to determine the critical containers and to establish the dengue transmission threshold valve for Jamaica based on the number of pupae per person established

1.3.7.2 Laboratory studies on the effect of temperature on the dengue vector, *Aedes aegypti*:

Temperature and vector competence study

In preparation for conduct of the temperature and vector competence study, one month was spent under the guidance of Dr Scott Weaver, Scientist, WHO Collaborating Centre at the University of Texas Medical Branch (UTMB), learning the following techniques:

- Culturing of Vero and C6/36 *Aedes albopictus* cells
- Preparation of infected blood meals

- Mosquito infection through membrane feeding
- Plaque assays – dengue
- Mosquito salivation
- Handling of infected mosquitoes
- Preparation of infected mosquitoes for assays

The methodology involves infecting *Aedes aegypti* mosquitoes with dengue viruses and incubating at room temperature then incremental temperatures up to 2˚C. At the end of the incubation period assays will be performed on mosquito specimen to ascertain the infectivity and transmission potential rates at each temperature.

Laboratory studies have not yet begun as we await the arrival of a membrane feeder (purchased by AIACC funds) and the necessary laboratory reagents. In the absence of all the required materials, arrangements will have to be made to return to UTMB for 1-2 months to run experiments.

Impact of temperature on insecticide susceptibility

The second part of the study involves investigating the impact of temperature on insecticide susceptibility in *Ae. aegypti* mosquitoes. WHO Bioassays have been conducted on the CAREC strain of *Ae. aegypti* (a strain which has never been exposed to insecticides and is kept in the CAREC insectary) at room temperature . This strain is known to be susceptible to insecticides and will be used as the control strain in experiments. These tests were conducted to obtain baseline data on the Lethal Concentration required to kill 90% of mosquito larvae (LC90) and the Lethal Time required to kill 90% of adult mosquitoes (LT90). Other experiments are to be conducted at room temperature on *Ae. aegypti* populations from four Caribbean islands. Tests involve incubating adult and larval mosquitoes before and after exposure to concentrations of liquid insecticides or insecticide impregnated papers at room temperature and then at temperatures of increments of up to 2˚C for 24 hours. The LC 90 and LT90 will be calculated for each population of *Ae. aegypti* in response to each insecticide tested at the different temperatures. Comparisons will be made between different temperatures and the response of the various populations of *Ae. aegypti* to insecticides tested.

2 Characterization of Current Climate and Scenarios of Future Climate Change

2.1 Activities Conducted

Activities consisted of building a climate database and using statistical downscaling to generate future scenarios. To develop capacity in database development a student was sent to The University of Puerto Rico, Mayaguez , for training. Data were also collected from stations in the Caribbean. For statistical downscaling several experts, including Dr. Rob Wilby and Dr. Tom Wigley, were invited to Jamaica at the start of the project to give advice on methodology. A student was also sent to Canada under the Canadian Adaptation to Climate Change in the Caribbean (ACCC) programme for training, and as a follow up a Canadian expert, Dr. Gary Lines of the Meteorological Service of Canada, Environment Canada, was brought to the Mona campus of the University of the West Indies to consolidate the training in January 2004. Dr. Aristita Busuioc, expert on statistical downscaling, visited Jamaica from September 17th to 23rd, 2005 to conduct an advanced course in downscaling for graduate students. Dr. Busuioc is a Lead Author for Chapter 11, IPCC 4th Assessment Report, and is based at the National Institute of Meteorology and Hydrology, Bucharest, Romania.

2.2 Climate Database

2.2.1 Description of scientific methods and data

The aim was to build an interactive climate database for use by researchers on the AIACC SIS06 project. Climate data were needed to document climate change and variability within the Caribbean, and particularly for the target countries. A database was therefore compiled in a format that was easy to handle, especially by researchers outside of the climate community. The database has the following characteristics:

1. Historical data of precipitation, maximum, minimum and mean temperatures for the Caribbean region. These data cover most of the Caribbean, including all the islands in the project and consist of daily precipitation, maximum and minimum temperatures for approximately 30 years. The data have been supplemented with records of wind, relative humidity and radiation where possible. Other climatic variables that were available through commercially produced global datasets were also extracted for the Caribbean and near Caribbean region.
2. Station and gridded data.
3. Both daily and monthly data
4. Easy selection of data according to temporal and spatial characteristics specified by the user.
5. Simple statistical manipulation of the data (means, deviations, climatologies, correlations, etc.).

In responding to the defining parameters above, the Caribbean Climate Interactive Database (CCID) version 1 was developed. The database was constructed and hosted at the Department of Physics, University of the West Indies, Jamaica and updated with voluntary contributions from sources within and outside the region. This database will become a resource for other areas of research, including other climate change related research. Its features are as described below:

Data: It was decided early in the project that the immediate need was for station data. Consequently emphasis was placed on amassing this, as opposed to gridded data. Two sources of data are currently utilised in CCID V.1. These are (i) Workshop data – Daily and monthly station data for 21 Caribbean territories contributed by Meteorological Service representatives at a January 2001 Caribbean Data Workshop held in Kingston, Jamaica. This is the base data for CCID. The data are of varying lengths and with varying amounts of missing data. (ii) GHCN data – These are monthly data, freely available from the global Historical Climate Network, which have been incorporated into the database. In both instances, the variables stored are maximum and minimum temperature and precipitation.

2.2.2 Results

The database has been designed in modular format with modules shown in Table 2.1

Module Name	Function
Data Storage and Retrieval	Handles the way climate data are stored. Creates suitable directory structure to facilitate fast and easy access of data
Statistics	Handles basic statistical calculations.
Data Update	Handles the data updates.
Visualizations	Handles all the visualizations necessary for data analysis. Can take information from the statistics and the Data Storage and Retrieval modules, and returns suitable visualizations (line graphs, contours, etc.) to the User Interface Module.
The User Interface	Allows the user to interact with all the other modules without knowing how each module is implemented.

Table 2.1: Modules and their functions in the CCID database

An easy to use and (almost) self explanatory interface has been designed which allows for easy access to and simple manipulation of the data. Some tasks facilitated by CCID include: selecting subsets of available data, saving data in alternative formats, plotting time series and scatter plots, performing simple correlations with selected time series or with global indices (e.g. Niño indices).

Availability: The database is currently available only on CD and on request. It will also be made available online. For further information please contact Dr. Michael Taylor (michael.taylor@uwimona.edu.jm).

2.2.3 Conclusions

The perceived limitations of CCID Version 1 are

1. Climate data within the Caribbean are hard to come by. Consequently updating of the existing database has proven difficult. No solution to this limitation has yet been found.
2. The database is currently limited to only three variables.
3. The database is currently limited to two data sources - Workshop and GHCN.
4. Many of the stations contain high percentages of missing data.

2.2.3.1 Usage and further development

Currently usage of the database was restricted to researchers working on this AIACC project. The database was made available to project members via CD or requested time series extracted and sent electronically. A few requests outside of the project for data have also been filled. Indices derived from the data have also been contributed to a joint paper on climate change.

Given funding, the further plans for the database include:

1. Updating the database through the pursuit of additional station data for the region. A schedule for updating will be devised and implemented.
2. Expanding the database to include additional variables and new data sources.
3. Expanding the database to include gridded data.
4. Making the database web accessible.

2.3 Scenario Generation

2.3.1 Description of scientific methods and data

A climate change scenario is a coherent and internally consistent description of the change in climate by a certain time in the future, using specific modelling technique and under specific assumptions about greenhouse gas emissions and other factors that may influence climate in the future. The future time refer to longer times than that considered when looking a climate variability, which refers to changes in patterns (e.g. precipitation patterns) in the weather and climate from one year to another. A climate change scenario cannot be regarded as a forecast of what the climate will be in the future because we cannot really forecast so far into the future what the emissions will be. In other words, a climate change scenario tells us what the climate may look like in the future under certain conditions. The scenarios generated below look at time slices in the 2020's (2011-2040), 2050's (2041-2070) and 2080's0 (2071-2100), and these were compared to the baseline, 1961-1990.

Scenarios can be generated using Atmospheric Global Climate Models (GCM), Coupled Atmospheric-Ocean Global Climate Models (AOGCM) which give coarse results over large grid (~ 4^o lat x 4^o long), and Regional Models, which have a small scale of approximately 50km. These models are referred to as dynamical models as they include equations of physics, chemistry, biological sciences and ocean-land-atmosphere interactions. Current temperature, pressure, relative humidity and winds are used as inputs into these models and many atmospheric parameters stepped in time are produced as outputs. The aim of statistical downscaling is to generate the climate scenarios for a smaller region or even a point, such as a weather station, using the output of a dynamic model for a larger region. The process consists of generating regression equations between predictands, such as temperature and precipitation, at the smaller site and climate predictors, such as pressure and vertical velocity, from available data sets, such as NCEP reanalysis data (1996). These regression equations are then used to find scenarios of future climate for the smaller site by using future values of the predictors generated by the dynamic model. The downscaling model used was the Statistical DownScaling Model (SDSM) developed by Wilby et al (2002).

The output of the climate models depended on the amount of greenhouse gases assumed. There are four different families of greenhouse gas scenarios, A1, A2, B1 and B2. These scenarios consist of different storylines with respect to population, economic and technological growth (Nakicenovic et al, 2000). The global climate of the 21st century for some of these families of greenhouse gases are shown in Figure 2.3.1.1 in terms of CO_2 emissions and concentrations, SO_2 emissions and expected rise in temperature and sea level. It can be seen that the A2 family was more aggressive in the emission of CO_2 than the B2 family. In this study both A2 and B2 scenarios were examined.

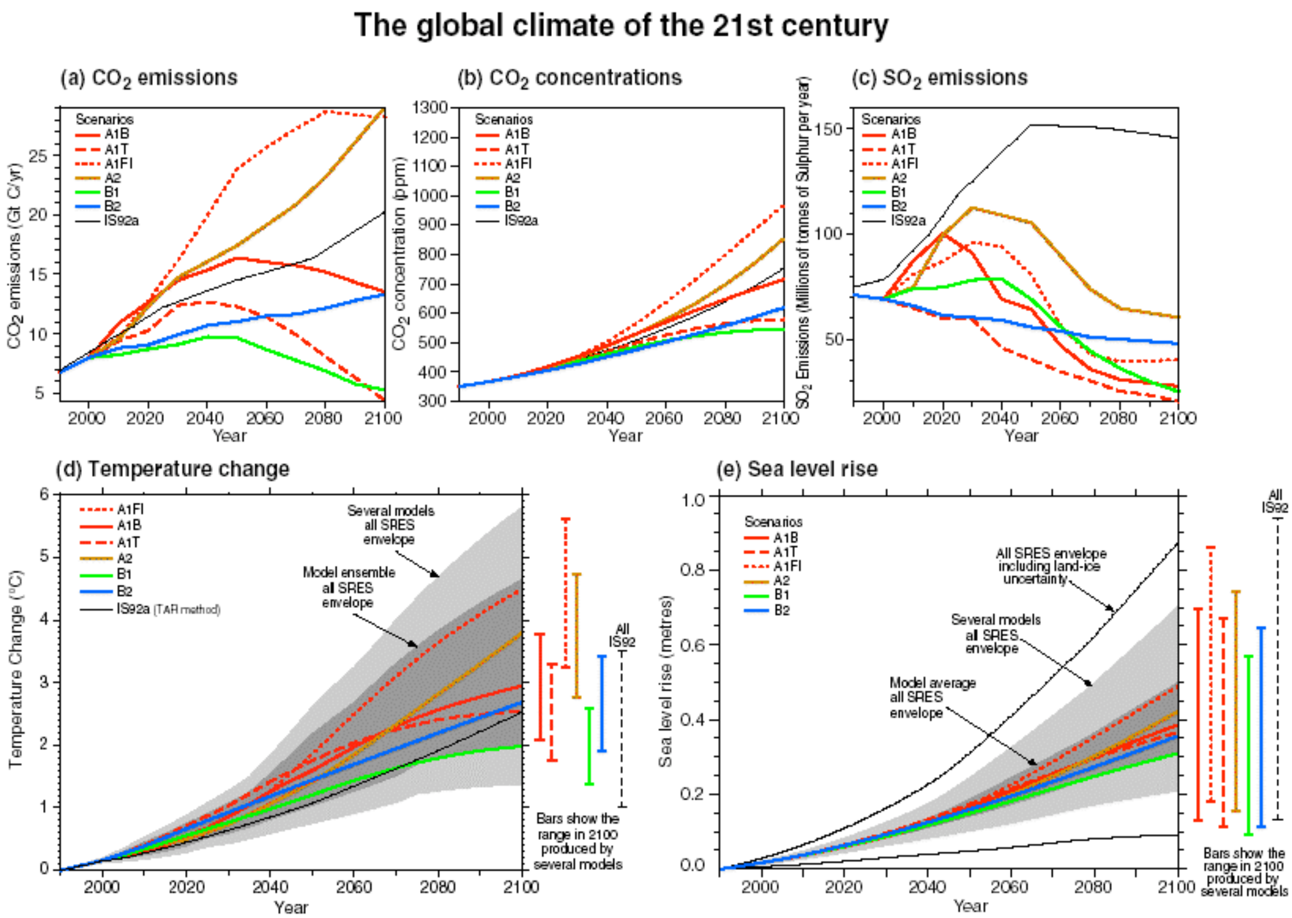

Fig. 2.1: Projected increases in CO_2 emissions, CO_2 concentrations, SO_2 emissions, temperature and sea level under various SRES and IS92a emission scenarios.

Figure 2.2 taken from Santer (2001) illustrates the skill of AOGCMs in simulating current precipitation and temperature in the Caribbean in terms of correlation patterns with respect to the annual climatology. In general, the models do not simulate current observed precipitation and temperature very well (low correlations), although Centre for Climate System Research (CCSR), Max-Planck Institute for Meteorology (ECHAM 3) and United kingdom Meteorological Office (HadCM2 and HadCM3) models reproduce temperature with fidelity, as do HadCM2 and HadCM3, precipitation. Temperature simulations correlated better with observed patterns than precipitation simulations, and the deviation in precipitation simulations was greater than that of temperature simulation. For precipitation HadCM3 provided the best correlation. Therefore the AOGCM outputs used in the Statistical DownScaling Model (SDSM) were those from HadCM3.

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Fig. 2.2: Pattern correlations between model outputs (identified on right) and climatology for temperature at 2 meter and precipitation, after Santer (2002)

A number of limitations exist when using the Statistical Downscaling method to generate scenarios. These include uncertainty in AOGCM (HadCM3) projections, incomplete station data and the difficulty in predicting precipitation values. The validity of downscaling is also based on the assumption that the regression equation which hold for current climate will hold for future climate.

2.3.2 Results

2.3.2.1 Temperature scenarios

The downscaled scenarios showed significant increases in the annual temperature for Trinidad, Barbados and Jamaica. The stations used were Piarco Airport in Trinidad, Caribbean Institute for Meteorology and Hydrology (CIMH) in Barbados, Sangster's International Airport (SIA), Norman Manley Airport (NM) and Worthy Park (WP) in Jamaica. The projected increases in temperature by the end of this century at these stations using HadCM3 output with A2 scenario were 2.2 ºC, 2.3 ºC, 2 ºC, 2 ºC and 3 ºC respectively (Table 2.2). These results agreed well with the average of the AOGCM scenarios for temperature increases for the region, which was 2.5 ºC. Table 2.2 also shows the scenarios for the 2020's and 2050's. Corresponding increases under B2 scenario are shown in the Table 2.3. Under this scenario the average temperature increase given by AOGCM was 1.7 ºC.

Time slice	Piarco	CIMH	Sangster's	Manley	Worthy Park
Baseline	-0.1	0	0	-0.02	0.1
2020's	0.7	0.4	0.5	0.63	0.9
2050's	2.2	0.9	1.1	1.26	2.0
2080's	2.2	2.3	2.0	2.05	3.1

Table 2.2: Temperature biases with respect to baseline data and increases for time slices at Piarco Airport in Trinidad, CIMH in Barbados, Sangster's International Airport, Norman Manley Airport and Worthy Park in Jamaica obtained by SDSM using output from HadCM3 run with A2 emission scenario.

Time slice	Piarco	CIMH	Sangster's	Manley	Worthy Park
Baseline	-0.1	0	0	0.2	0.1
2020's	0.8	0.50	0.6	0.7	0.9
2050's	1.1	0.7	1.0	1.3	1.5
2080's	1.6	0.7	1.5	1.8	2.3

Table 2.3: Same as Table 2.2 except for with B2 emission scenario

There were discrepancies with AOGCM models for precipitation. Most showed decreases in precipitation while others showed increases. The downscaled scenarios of precipitation showed both increases and decreases for some Caribbean locations. Downscaled scenarios using HadCM3 outputs with A2 SRES emissions showed increases of the annual precipitation for Piarco Airport in Trinidad, CIMH in Barbados and Worthy Park in Jamaica of 1.8, 3.1 and 2.1 mm per day respectively by the end of the century. Corresponding projections for Norman Manley Airport (NM) and Sangster's International Airport in Jamaica gave decreases of -0.43 and -0.7mm per day respectively (Table 2.4). The AOGCM results gave an average precipitation decrease of 8mm/day. Therefore the downscaled results for precipitation do not agree well with the AOGCM results, unlike for temperature.

Time slice	Piarco	CIMH	Sangster's	Manley	Worthy Park
Baseline	0.02	0.7	1.9	1.93	0
2020's	-0.02	0.5	-0.2	-0.12	0.4
2050's	1.1	2.9	-0.4	-0.2	1.1
2080's	1.8	3.1	-0.7	-0.43	2.1

Table 2.4: Precipitation biases with respect to baseline data and increases for time slices at Piarco Airport in Trinidad, CIMH in Barbados, Sangster's International Airport, Norman Manley Airport and Worthy Park in Jamaica obtained by SDSM using output from HadCM3 run with A2 emission scenario.

For B2 emission scenario used with HadCM3 outputs the corresponding results for Piarco Airport in Trinidad, CIMH in Barbados, Sangster's International Airport, Norman Manley Airport and Worthy Park in Jamaica were 1.6mm/day, 2.6mm/day, -4.3mm/day, -2.7mm/day and 1.1mm/day. The AOGCM results gave an average precipitation decrease of 37mm/day.

The downscaled scenarios using A2 emissions scenarios at the individual stations will now be discussed. Included in the diagrams are the observed data (obs), Baseline (NCEP), ECHAM4 A21, HadCM3 A21 and SDSM (HadCM3):

- The observed data (obs) are observed historical data from the period 1961-1990 for different stations.
- Baseline (NCEP) is the SDSM model simulation (1976-1990) of the present day climate (1961-1990) in the study area using predictors from the National Centre for Environmental Prediction (NCEP) re-analysis dataset.
- ECHAM4 A21 and HadCM3 A21 are both coupled Atmospheric-Ocean Global Climate Models (AOGCM's) using A2 emissions scenarios, where ECHAM4 A21 is a model developed at the Max-Planck-Institute for Meteorology and HadCM3 A21 is a model developed at the UK Hadley Centre for Climate Prediction and Research.
- SDSM (HadCM3) is the downscaled scenario from the SDSM model using GCM derived predictors from HadCM3 with the A2 emissions scenario.

Results from both ECHAM4 A21 and HadCM3 A21 were taken from the Canadian Climate Impacts Scenarios website (www.cics.uvic.ca/scenarios) for all stations studied.

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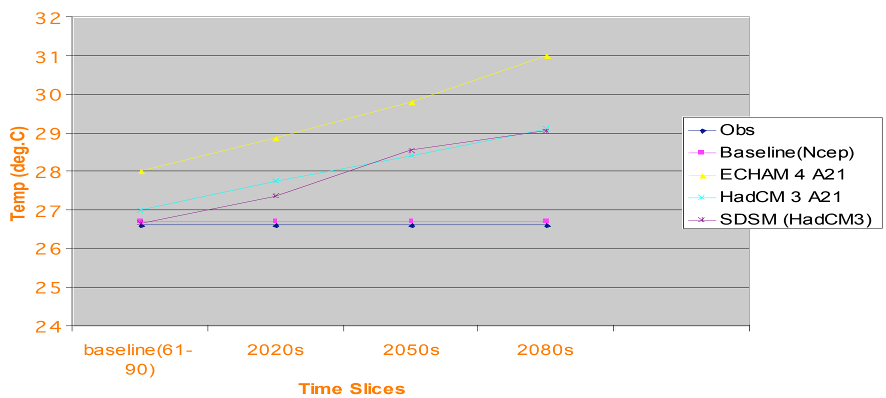


Fig. 2.3: Observed and baseline (NCEP) temperatures and temperature scenarios at Piarco Airport in Trinidad for present (1961-90), 2020's, 2050's and 2080's time slices obtained by SDSM using HadCM3 with A2 emission scenario. Corresponding results for the Caribbean region given by HadCM3 and ECHAM4 are also shown.

Baseline (NCEP) showed an underestimation when compared to the observed data for the period 1961-1990 at Piarco Airport in Trinidad. The downscaled scenario showed a bias of -0.1 when compared to the observed data for the period 1961-1990. (Table 2.2), but there was a significant increase of the annual temperature for Trinidad of 2.2°C at the end of the century. The corresponding increases for the HadCM3 A21 and ECHAM 4 A21 were 2 °C and 3 °C respectively (Figure 2.3).

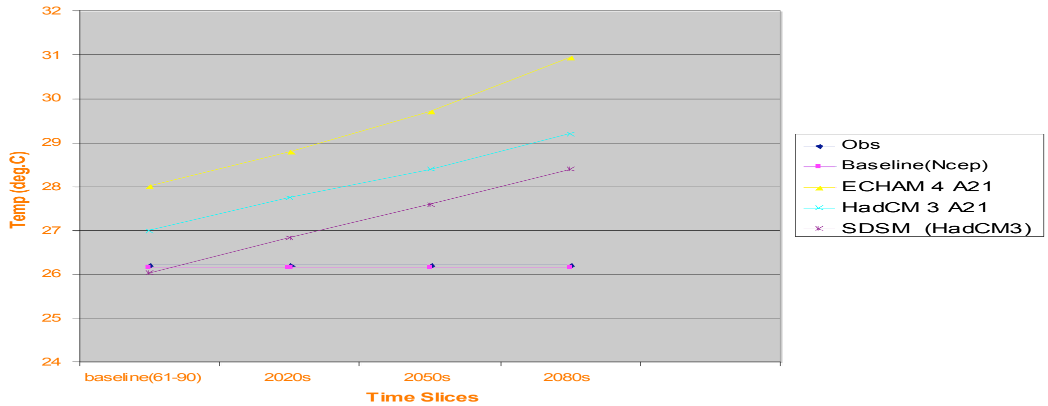


Fig. 2.4: Same as for Fig. 2.3 but for CIMH in Barbados.

There was no bias between the observed data (obs) at CIMH in Barbados and Baseline (NCEP). The downscaled scenario (SDSM (HadCM3)) reproduced the observed data for the period 1961-1990 very well; there was also no bias (Table 2.2). ECHAM4 A21 shows 3 ºC temperature increases whereas a 2.2 ºC increase was observed for HadCM4 A21 at the end of the century. The downscaled scenario for CIMH in Barbados showed an increase of 2.3 ºC in the 2080's, which was consistent with the global climate model increases using A2 emissions scenarios (Figure 2.4).

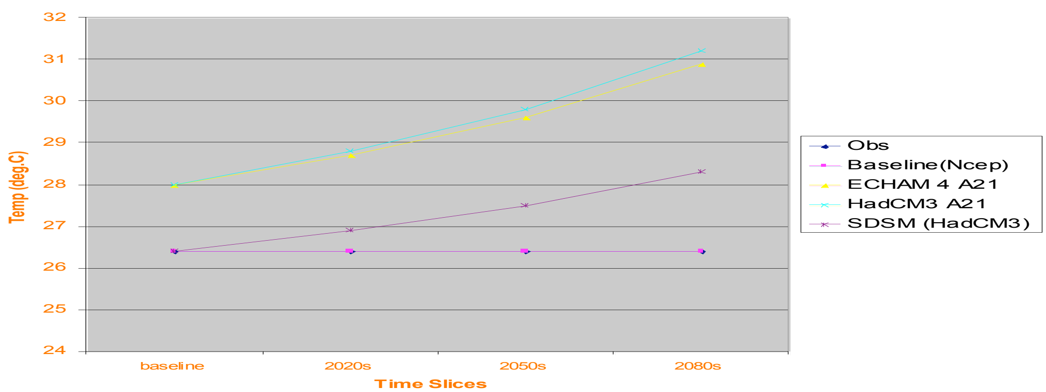


Fig. 2.5: Same as for fig. 2.3 but for Sangster's International Airport (SIA) in Jamaica.

For Sangster's International Airport (SIA) the Baseline (NCEP) and the downscaled scenario reproduced the period 1961-1990 very well when compared to the observed data (Table 2.2). Temperature increases of 3 ºC and 3.2 ºC were observed for ECHAM4 A21 and HadCM3 A21 respectively. Corresponding increases of 2 ºC was observed for the downscaled scenario for Sangster's for the ending of the century (Figure 2.5).

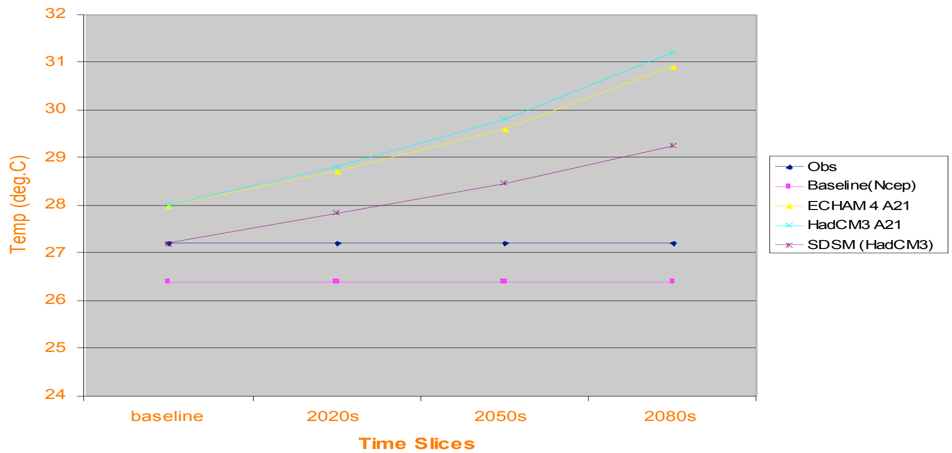


Fig. 2.6: Same as for Fig. 2.3 but for Norman Manley (NM) in Jamaica.

For Norman Manley, SDSM using the NCEP data (Baseline (NCEP)) underestimated the observed data for the baseline period, 1961-1990. The downscaled scenario using HadCM3 compared well with the observed data for the same period (bias of - 0.02 ºC) (Table 2.2). The increases observed for SIA above for the ECHAM4 A21 and HadCM3 A21 models (Figure 2.5) were also observed for Norman Manley (Figure 2.6). At the end of the century, the downscaled scenario shows annual increases of 2ºC.

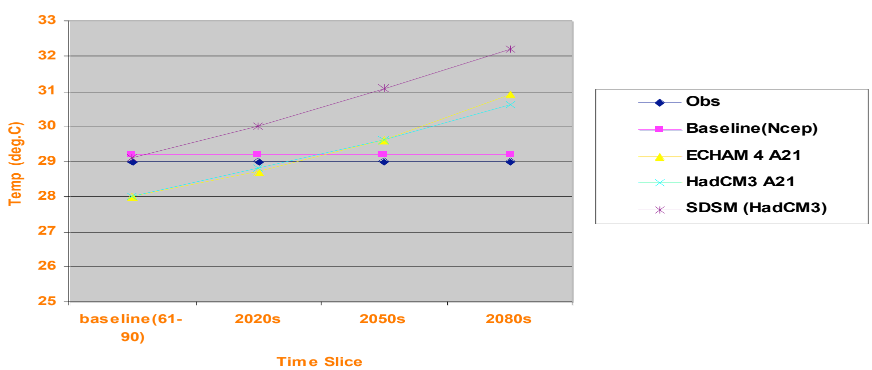


Fig. 2.7: Same as for Fig. 2.3 but for Worthy Park (WP) in Jamaica.

There was an overestimation for Baseline (NCEP) when compared to the observed data for the period 1961-1990. Underestimation of 0.1was observed when the downscaled scenario (HadCM3) was compared with the observed data for the period 1961-1990 (Table 2.2). Temperature increases for ECHAM4 A21 and HadCM3 A21 are the same as the ones above with Norman Manley and Sangsters International Airports (Figure 2.5, Figure 2.6 and Figure 2.7). The downscaled scenario for Worthy Park shows an increase of 3.1 ºC in the annual temperature at the end of the century (Figure 2.7)

2.3.2.2 Precipitation scenarios

Precipitation scenarios were done for the above stations and are discussed below.

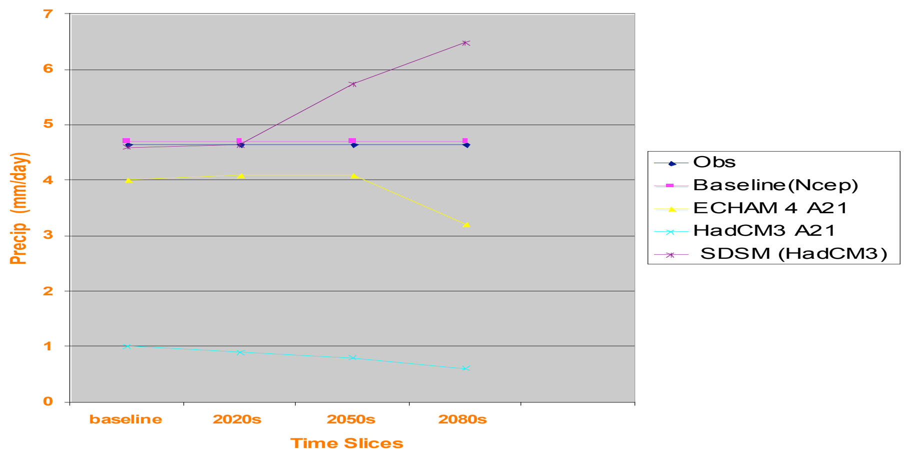


Fig. 2.8: Observed and baseline (NCEP) precipitation and precipitation scenarios at Piarco Airport in Trinidad for present (1961-90), 2020's, 2050's and 2080's time slices obtained by SDSM using HadCM3 with A2 emission scenario. Corresponding results for the Caribbean region given by HadCM3 and ECHAM4 are also shown.

The Baseline (NCEP) reproduced the baseline period, 1961-1990, fairly well when compared to the observed data (obs) at Piarco Airport. A bias of 0.02 was seen when the downscaled scenario was compared to observed data (Table 2.4) for the period 1961-1990, and a precipitation increase of 1.8mm/day was observed for the downscaled scenario at the end of the century. The ECHAM4 A21 and HadCM3 A21 models showed decreases of 0.9mm/day and 0.4 mm/day respectively at the end of the century (Figure 2.8).

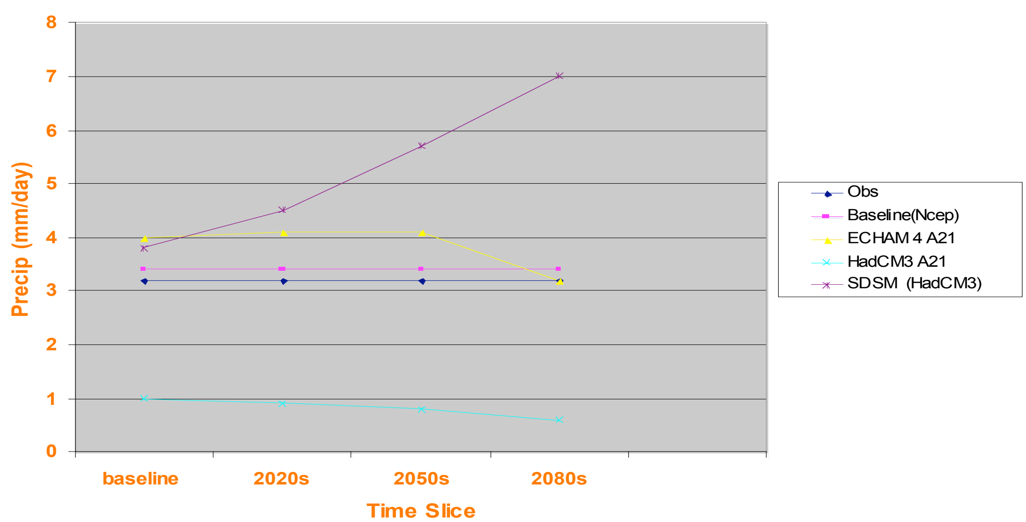


Fig. 2.9: Same as for Fig. 2.8 but for CIMH in Barbados

For CIMH in Barbados a bias of 0.7 is observed when the downscaled scenario was compared with the observed data for the baseline time period, 1961-1990 (Table 2.4). Precipitation decreases of 0.9mm/day and 0.5mm/day were observed for the ECHAM4 A21 and HadCM3 A21 models but an increase in precipitation of 3.1mm/day were projected for the end of the century for the downscaled scenario (Figure 2.9).

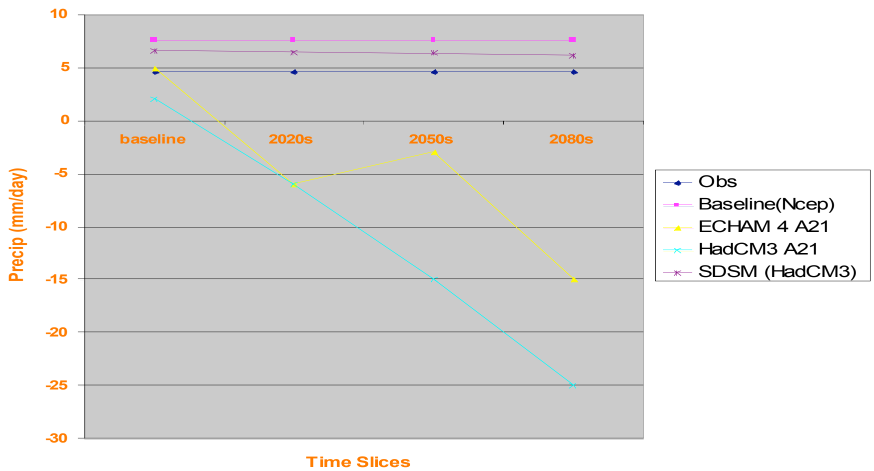


Fig. 2.10: Same as for Fig. 2.8 but for Norman Manley (NM) in Jamaica.

The Baseline (NCEP) model did not reproduce the observed data well, but showed an overestimation when compared to the observed data for the period 1961-1990.

A bias of 1.93 was observed for Norman Manley when observed data was compared to the downscaled scenario for 1961-1990 (Table 2.4). ECHAM4 A21 and HadCM3 A21 show decreases in precipitation of 16mm/day and 26mm/day respectively at the end of the century. Corresponding precipitation decrease of 0.43 mm/day was observed for the downscaled scenario for Norman Manley in Jamaica (Figure 2.10).

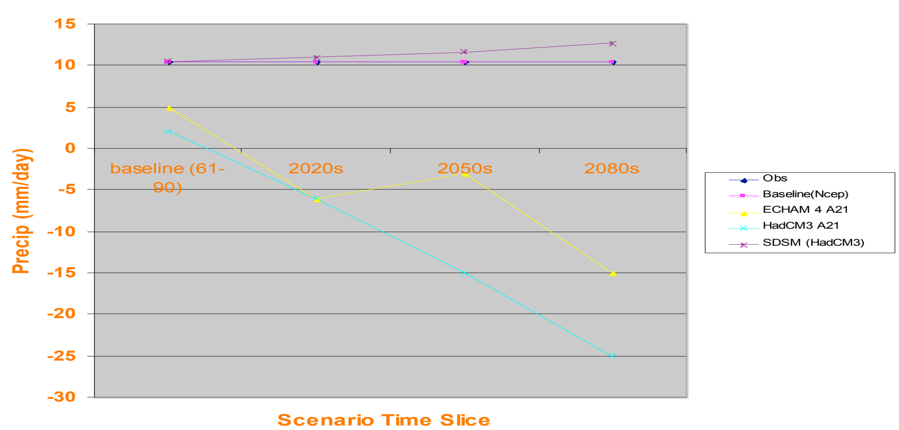


Fig. 2.11: Same as for Fig. 2.8 but for Worthy Park in Jamaica.

For Worthy Park the observed data for the baseline period, 1961-1990 was reproduced well by Baseline (NCEP). Also, the downscaled scenario reproduced the observed data well for the same period (Table 2.4) where no bias was observed. Precipitation decreases for ECHAM4 A21 and HadCM3 A21 were the same as that for Norman Manley in Jamaica (Figure 2.10), where fluctuation patterns in precipitation was observed for the ECHAM4 A21 model. The downscaled scenario shows an increase in precipitation of 2.1mm/day at the end of the century (Figure 2.11).

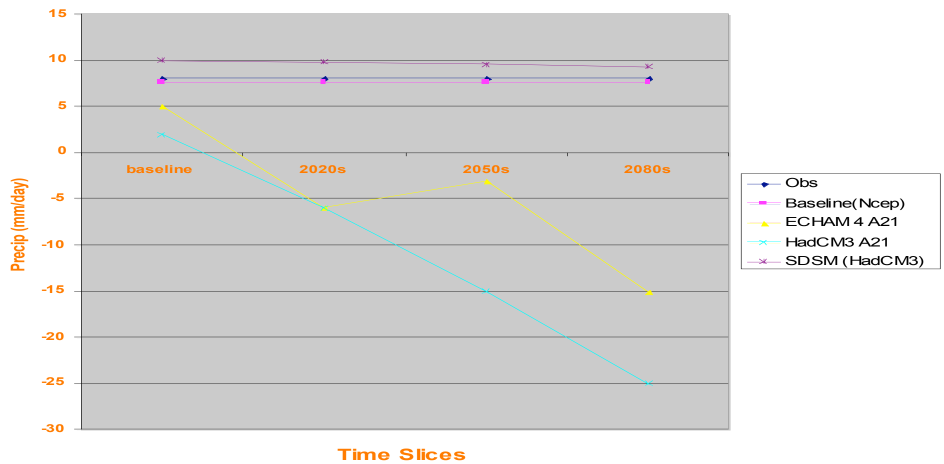


Fig. 2.12: Same as for Fig. 2.8 but for Sangster's International Airport (SIA) in Jamaica

The bias obtained when Baseline (NCEP) was compared to the observed data was very small for Sangster International Airport. However, an overestimation of the period 1961-1990 was observed when the downscaled scenario was compared to the observed data with a bias of 1.9 (Table 2.4). The same precipitation patterns for ECHAM4 A21 and HadCM3 A21 that were the same as for Worthy Park and Norman Manley (Figures 2.10, 2.11 and 2.12). The downscaled scenario shows a decrease in precipitation of 0.7mm/day for Sangster at the end of the century, but it is not consistent with the GCMs decreases.

2.3.3 Conclusions

The temperature scenarios from AOGCMs and from statistical downscaling were consistent, all showing expected increases. Because of this consistency we have some confidence that temperatures in the Caribbean are likely to increase by about 2 ºC by 2080. In addition the SDSM results agreed closely with the AOGCM results so that the level of confidence in temperature increases is greater. Scenarios for rainfall were however much less consistent with most AOGCMs showing decreases in precipitation while other show increases. There are cases (Piarco Airport in Trinidad, CIMH in Barbados and Worthy Park in Jamaica) where AOGCMs predicted a decrease in precipitation but SDSM gave an increase. The precipitation results are therefore highly uncertain.

As will be shown later, temperature is the main climate component which controls the potential of dengue epidemic and so the temperature results obtained are of great importance to the project. As described in Chapter 1, a temperature increase of 2 ºC from 30° C to 32° C can shorten the extrinsic incubation period (EIP) of the viruses from 12 to 7 days (for dengue type 2) and decreasing the incubation period by 5 days can lead to a threefold higher transmission rate of dengue. Thus the main impact expected from increases in temperature is an increase in the epidemic rate for the disease. On the other hand the precipitation results are indifferent for the spread of the disease. The vector of the disease, mosquitoes, breed in stagnant waters, but precipitation is not a necessary prerequisite. Precipitation will provide breeding sites outdoors in uncovered containers, but in dry conditions water is stored in containers, mainly in large drums, which provide alternate breeding sites.

3 Impacts and Vulnerability

3.1 Activities Conducted

At the start of the project several persons with expertise in climate and health, including Prof. Ulisses Confalonieri, Dr. Joan Aron, Dr. Henry Diaz and Dr. Roger Pulwarty, were invited to a workshop in Jamaica to advise on planning and executing activates for the Project (Fig. 3.1). A second workshop was held in mid-stream to evaluate results to date and revisit planned activities (Fig. 3.1). Advisers were Dr. Joan Aron and Dr. Xianfu Lu. It was then decided to omit one of the activities planned for in the project proposal, that of mapping indices of disease and vectors and climate patterns, using a GIS system. This was on account of the fact that, although the data being obtained in the prospective study were of sufficient quantity and quality, it was not sufficiently distributed throughout the islands to warrant a GIS system. Instead a new component was added to the project with the consent of the AIACC directorate, that of laboratory studies to confirm the effects of temperature on vector competence and insecticide susceptibility of the dengue vector, which was described in section 1.3.7.2 and not elaborated on below since the activity is still ongoing and awaiting the arrival of equipment. A student, Roxanne Stennett, was also sent to Summer Colloquim on Climate and Health, **N**ational Center for Atmospheric Research (NCAR)**,** 21 - 28 July, 2004.

The various activities were carried out in this project component:

a. Retrospective Study,

b. Prospective Study, which involved field work,

c. Socioeconomic Study, which included field work.

Fig. 3.1: Participants in the First Consultation and Planning Meeting, Ocho Rios, Jamaica, April 21-22, 2002

Fig. 3.2: Some of the participants at the Second Consultation and Planning Meeting, Negril, May 10 -11, 2004

3.2 Retrospective Study

3.2.1 Description of scientific methods and data

The objectives of this component were to:

- Determine the nature and extent of the association between climate and the incidence of dengue across the Caribbean.
- Quantify the association in terms of a measurable parameter such as temperature, and develop a procedure to predict the potential for onset of dengue.

The approaches selected to achieve the objectives were as follows:

- Investigation of the influence of climate on the epidemics examining temperature and precipitation association.
- Investigation of the seasonality of the epidemics.
- Investigation of the extent of association of the epidemics with ENSO (El Niño, La Niña, Neutral) events.
- Formulation of index/indices to predict the potential for the onset of dengue in terms of an easily measurable climate variable such as temperature.

Data on reported cases of dengue were provided by the Disease Surveillance Unit, CAREC (Caribbean Epidemiology Centre) in Trinidad, and were derived from reports submitted from the various countries' Ministry of Health. The data which spanned the period 1980 to 2001 (except for Trinidad and Tobago where the data were available up until 2003) were in the form of annual totals for 1980 to 2001, and also on a 4-week period basis from 1992 to 2003 (without 1993 and 1995) for Trinidad, and on a monthly basis from 1995 to 1999 for Barbados and Jamaica. (Disease reporting for CAREC member countries is done on a system of the epidemiology week.)

3.2.1.1 CAREC data

Since 1975 CAREC, a PAHO/WHO centre, has collected data on diseases, including vector-borne diseases (VBDs), from the ministries of Health in the CAREC Member Countries (CMCS). CMCs now number 21 countries with an overall total of about 6 million, ranging from a large population of 2.5 millions in Jamaica in the north to smaller countries such as Montserrat with only about 12,000 persons. Such data are sent to CAREC on a monthly basis, and an analysis of the data is done for appropriate advice to all CMCs. The faithfulness of the accurate and timely reporting is one of the limiting factors that could make or break the value of the data for appropriate action in the region. CMCs have also been encouraged to report to the CAREC the surveillance and control of vectors of disease such as the mosquito Aedes aegypti which is omnipresent in the 21 CMCs except the Cayman Islands. This latter attempt has only had limited success.

Data analysis consisted of the analysis of the time series of the reported cases of dengue fever and their rates of change, mean temperature, mean precipitation, anomalies of temperature and precipitation; correlation analysis including lag; formulating an index useful to determine the period of onset of the dengue fever based on the temperature. The rate of change mentioned here is equal to the reported cases in a given year minus that in the previous year, and is expected to provide more features of the pattern of variation of the disease. The apparent seasonality of the epidemic was studied by examining the cases reported every 4 weeks (4 week month) or every calendar month for the period 1996 to 2003 for Trinidad, and from 1995 to 1999 for Barbados and Jamaica. A 4 week month as used in this report is a time period spanning 4 consecutive weeks. Four week month data sets were used for Trinidad and Tobago while calendar month data were used for Barbados and Jamaica. The choice of 4 week months or calendar months was based on the available format of data. However, this choice should not cause a problem as a calendar month is almost 4weeks. An anomaly (SA) as used in this paper was:

SA = (measured value – average value)/standard deviation.

In the study of the patterns of climate variables and reported cases charts were used that were produced by Excel. The correlation analysis was accomplished using the statistical tool kit SPSS. The sorting of El Niño and La Niña episodes, for the period 1980 to 2000, were according to the NOAA-CDC MEI index classification and they were:

El Niño episodes: 1982/83, 1986/87, 1992/93, 1994/95 (weak), and 1997/98.

La Niña episodes: 1988/89, 1998+/00

3.2.2 Results

Results are summarized in Figures 3.3 to 3.4 and Tables 3.1 to 3.2. Figure 3.3 shows the geographical distribution of reported dengue fever cases during the period 1980 to 2001 across the Caribbean. Incidence of dengue shows an increase from south to north. The southern part is warmer and moister (The Longman Atlas For Caribbean Examinations; 5th Impression, 1994; Edited by Mike Morrissey). This warm moist climatic condition may be a reason for higher incidence of dengue in the southern part, which provides some evidence for association of the dengue epidemics with climate.

THE CARIBBEAN

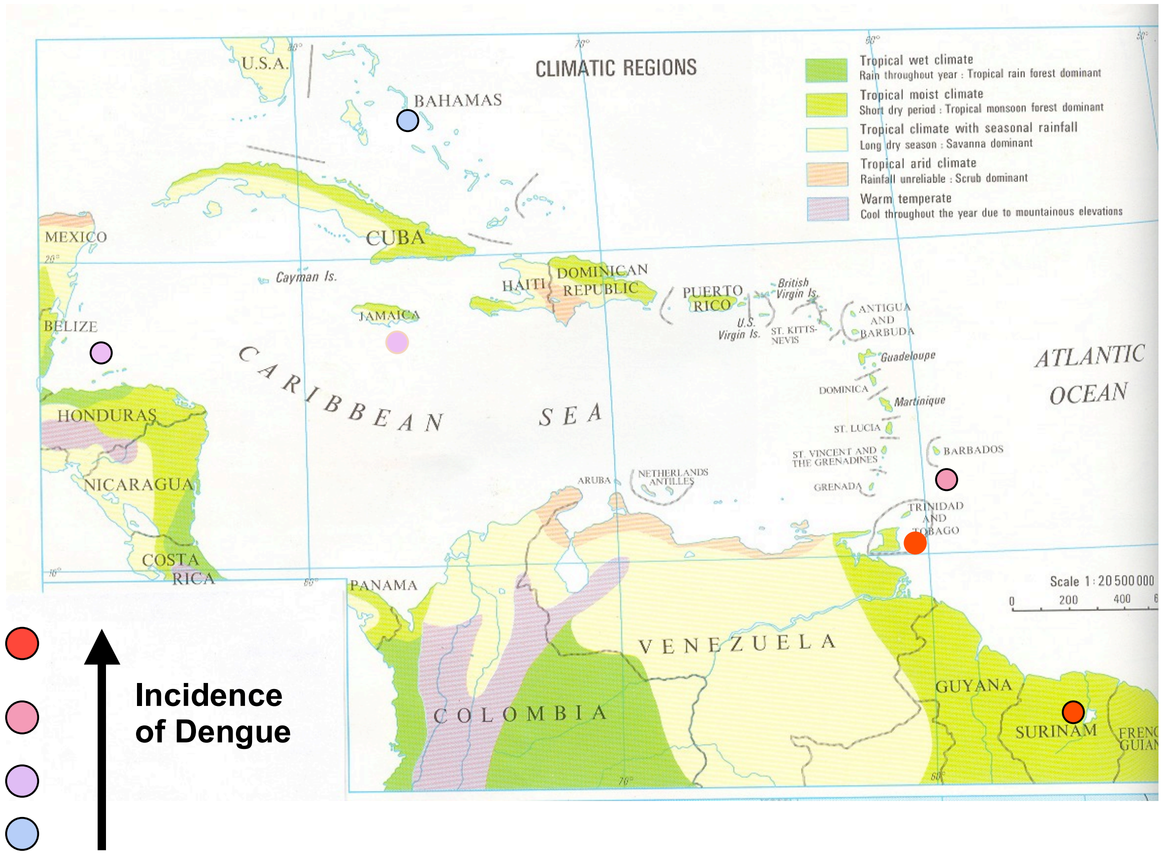


Fig. 3.3: Geographical distribution of reported cases

Figure 3.4a illustrates the time series of annual reported cases and figure 3.4b illustrates the variability in the 4 weekly reported cases in the Caribbean. The coloured arrows in figure 3.4a indicate El Niño, El Niño+1, and La Niña years. From figure 3.4a it is apparent that the probability of an epidemic during an El Niño period (El Niño and El Niño+1 years) is higher. The results given in Table 3.1 further support this inference. Thus, it appears that dengue outbreaks have a strong association with El Niño events, probably because the latter part of the El Niño years is warmer and the early part of the El Niño+1 years is wetter and warmer. Correlation of annual reported cases with temperature and rainfall indicated that the association with temperature is much stronger than that with rainfall, as shown in Table 3.2. The variability shown in figure 3.4b indicates that the epidemics have a well defined seasonality. It occurs in the latter half of the year. The values plotted in figure 3.4b are 4-week values averaged over all the countries considered in the study. A total of 21 countries were considered. It needs to be mentioned that this feature was clearly present in the patterns of the disease for the individual countries. Examples are in figures 3.5 to 3.12.

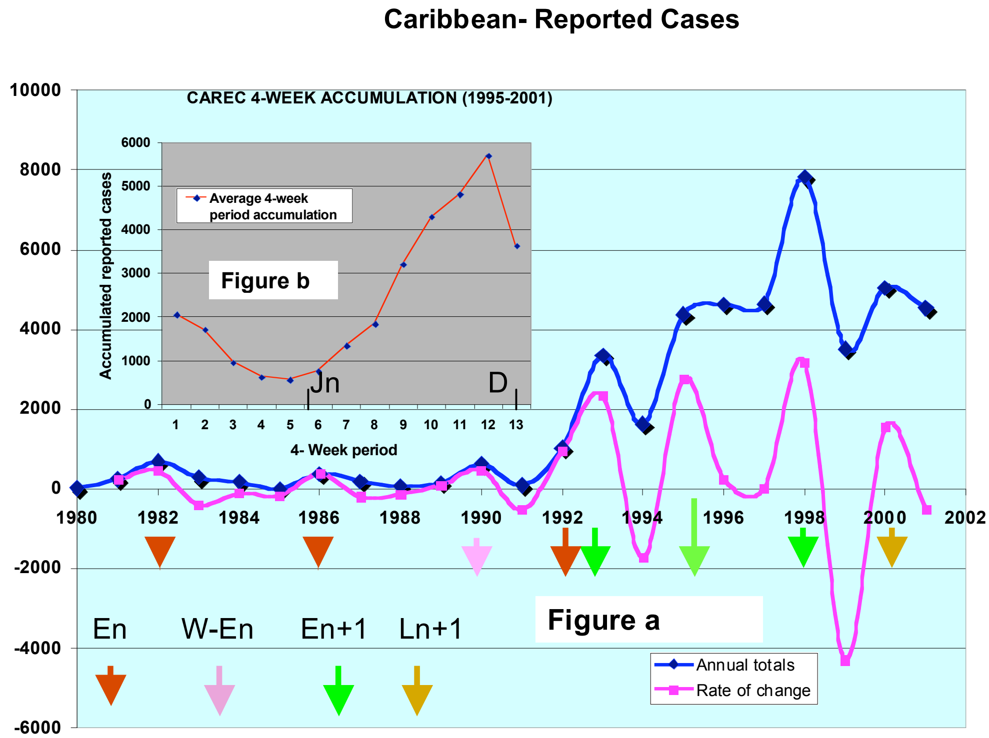


Fig. 3.4: (a) Time series of annual reported cases and (b) the 4 week variability.

REGION	TOTAL	El Nino & +1	La Nina	Neutral
Caribbean	8	7	-	1
T & T	8	6	-	2
Barbados	6	5	-	1
Jamaica	5	4	-	1
Belize	4	3	1	

Table 3.1: Distribution of dengue peaks among the ENSO phases in selected countries.

COUNTRY	TEMPERATURE	RAINFALL
	r: p	r : p
T & T (1980-2001)	0.5663 : 0.006	Not significant
El Niño (1980-2001)	0.6798 : 0.031	Not Significant
El Niño (1990-2001)	0.8271 : 0.0423	0.8784 : 0.0213
Barbados (1980-2002)	0.479 : 0.0207	Not Significant
El Niño (1980-2002)	0.5854: 0.0584	Not significant
El Niño (1990-2002)	0.6261 : 0.1326	Not significant

Table 3.2: Correlation results of annual dengue cases with temperature and rainfall in Trinidad and Tobago, and Barbados.

Figure 3.5, which is for Trinidad and Tobago, illustrates the 4- weekly variability of reported cases, temperature and rainfall. The period covered here is from 1996 to 2003. The figure shows that the warming occurs first, this is followed by rainfall after which, the dengue epidemic occurs. Thus we see a simple pattern among onset of the epidemic, warming, and precipitation. This pattern was easily observable in other countries as well. An example is Barbados, shown in Figure 3.6. The period considered in Barbados was from 1995 to 1999.

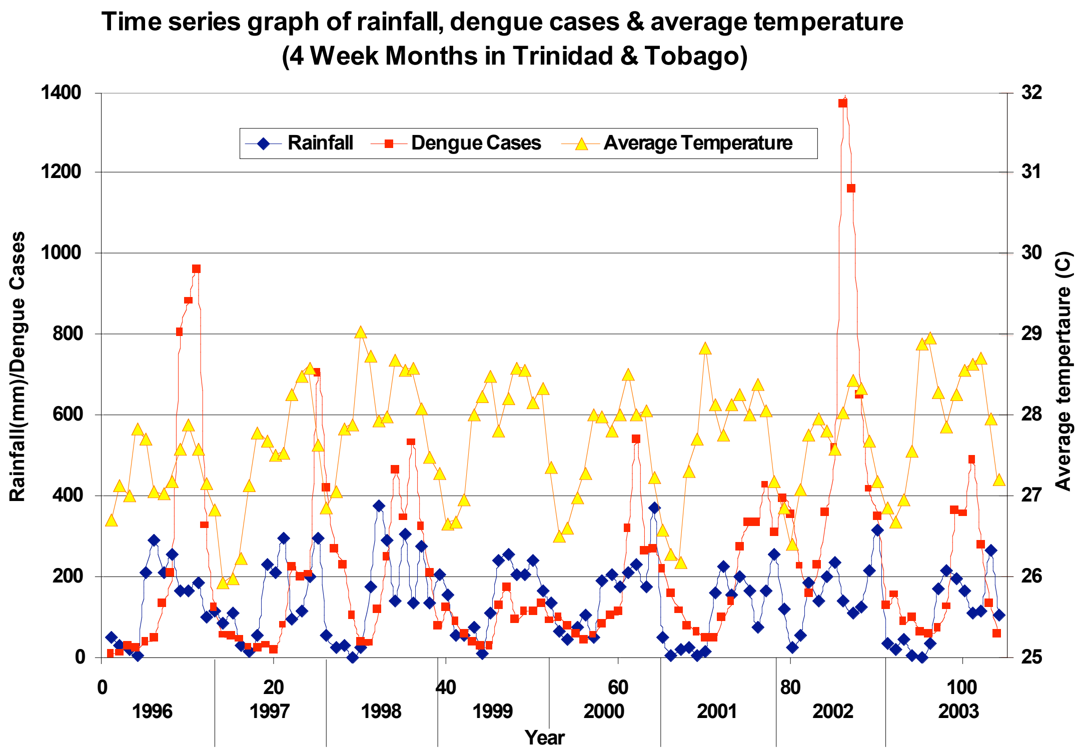


Fig. 3.5: Time series of rainfall (blue), dengue cases (red) and average temperature (orange) for Trinidad and Tobago

Detailed analysis of the disease, temperature and rainfall patterns including lag correlation studies revealed the following results:

- Statistically significant lag existed between temperature and the epidemics. If attention was focused on the peaks, the observed lag corresponded to the time that elapsed between the early temperature peak and epidemic peak, in a year. Lag periods observed were three to seven 4-week periods/months. Results are given in tables 3.3 and 3.4. The lag between temperature peaks and the dengue peaks are clearly visible in figures 3.5 and 3.6. Lag, of the order of a few months, between dengue cases and temperature has been observed by others as well (Wegbreit, 1997).
- Statistically significant lag existed between rainfall and the epidemic peaks. Lag periods observed were one to three 4-week periods/months.
- Lag between temperature and an epidemic was generally greater than the lag between the rainfall and the epidemic.
- During years with an early warmer period, the onset of the disease appeared to occur early and the onset was immediately after the previous epidemic. Observed onset times are given in tables 3.3 and 3.4 for Trinidad, Barbados and Jamaica. This feature was more pronounced if the previous year was a warmer one. Examples include; 1997/98, 2001/02, 2002/03 in Trinidad and 1997/98 in Barbados (figures 3.5 and 3.6).

- In any year, onset appeared to occur during the summer period and after a few weeks of the early temperature peak. The lapse time varied from 0 to about 8 weeks. The lapse time was smaller (≤ 4weeks) when the early part of the year is warmer than normal. The early peak in temperature (denoted by Tep in the following discussions), temperatures at onset and visually estimated lapse times are given table 3.5. In Jamaica, annual temperature pattern does not exhibit a clear bimodal pattern. The pattern is more unimodal. The term Tep, when applied to Jamaica, refers to the peak in temperature.
- Moisture availability (rainfall) appeared to be necessary for the onset, but the amount of moisture did not appear to be critical for the onset and this can be seen from the pattern shown in figures 3.5 and 3.6. Moisture is required for vector breeding and subsequent transformation of eggs to larvae, and then to pupae, and finally to the mosquitoes. However, higher rainfalls (causing floods) can wash away the mosquito eggs and larvae. But water can remain stagnant after the rain has ceased.

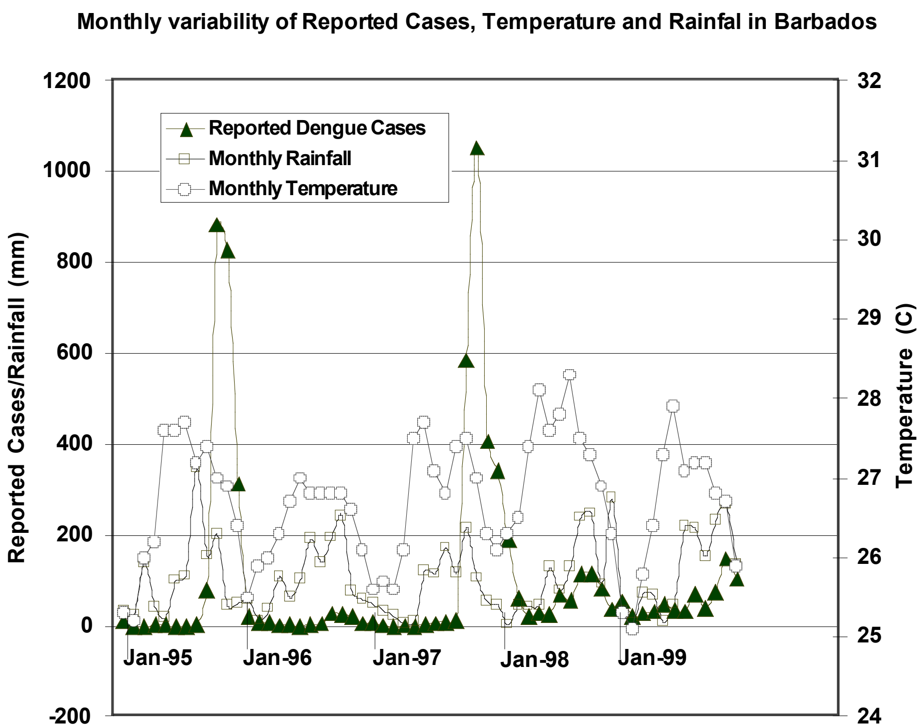


Fig. 3.6: Time series of rainfall, dengue cases and average temperature for Barbados

The next task to address was the formulation of index/indices suitable to predict the onset of dengue. Two schemes are presented. First deals with the use of the onset time of Tep and that of the 4week monthly/calendar monthly temperatures. As mentioned before, the early temperature peak was close to the onset of the disease and the identification of the early peak was not too difficult when the temperature pattern was known. From results given in table 3.5, it can be inferred that for Trinidad and Tobago Tep varied from 27.8 ºC to 29.0 ºC with an average of 28.3 ºC, and the average lapse time was one 4-week period. For Barbados Tep varied from 27 ºC to 28.1 ºC with an average of 27.8 ºC, and the average lapse time was about 1.5 months. For Jamaica Tep was 30 ºC for both 1995 and 1998, and the average lapse time was 1 month. Further for Trinidad and Tobago the dengue onset temperature varied from 27.0 ºC to 28.9 ºC with an average of 27.9 ºC. The onset temperatures for the individual years were within 1 ºC of the average value. For Barbados onset temperature varied from 26.8 ºC to 27.6 ºC with an average of 27.2 ºC. The onset temperatures for the individual years were within 0.4 ºC of the average value. For Jamaica onset temperatures were 28.8 ºC (1995) and 29.6 ºC (1998), with an average of 29.2 ºC. These results show that use of measured temperature to predict onset of the disease is practical, using the time of the Tep and the average lapse time or using the county's average temperature estimated for disease onset (27.9 ºC for Trinidad and Tobago, 27.2 ºC for Barbados and 29.2 ºC for Jamaica). However, the following remarks have to be made about this scheme. From figures 3.5 and 3.6 it is clear that the 4week monthly/calendar monthly temperature follows more or less an oscillatory pattern. Also the temperature peaks are broad. These features impose limitations on the use of the country's average onset temperatures (27.9 ºC for Trinidad and Tobago, 27.2 ºC for Barbados and 29.2 ºC for Jamaica), and the time of Tep together with the average lapse time to gauge the onset time of dengue, unless the user is extra careful. Reasons being, because of the oscillatory pattern of the temperature, county's average onset temperature can be observed on the rising side as well as on the falling side of the temperature peak and there can be a considerable time gap between the two observations. From the results of this work it appears that the more acceptable would be the observation on the falling side of the temperature peak. The broadness of the temperature peak causes less accurate estimation of the time of Tep.

A second scheme incorporates the lag and deals with the use of a data set obtained after smoothing the temperature variability. In the smoothing process Trinidad temperature data for the years 1992, 1994, and 1996 to 2003 were considered in the form of 4week monthly lumps, Barbados data for the years 1995 to1999 were considered monthly (calendar), and Jamaican data for 1995 and 1998 were considered monthly (calendar). In the smoothing process following moving average in the temperature (MAT) was calculated for every year.

Moving average temperature (MAT) = $\dfrac{1}{M}\sum_{N=1}^{M}\theta_N$.

In Trinidad θ_N is the average temperature during the Nth 4-week period and in Barbados and Jamaica it is the average temperature during the Nth month. The indices N and M vary from 1 to 13 in Trinidad and 1 to 12 in Barbados and Jamaica. According to this definition of MAT, the first value of MAT, that is for M = 1 is the same as the average temperature for the first 4-week period in Trinidad (first month in Barbados and Jamaica) in a given year.

Figures 3.7, 3.8, 3.9, and 3.10 show how the reported cases vary in relation to the parameter MAT in Trinidad. Interestingly it was observed that the disease onsets and strengthens when the MAT is around 27.3 ºC for Trinidad, as seen in the figures. The value of 27.3 ºC was the average of the MAT values at onset. The MAT values at onset for different years are given in Table 3. 5 and it is evident that individual values for Trinidad fall within 0.4 ºC of the average (27.3 ºC) except for 1998. For 1998 deviation is 0.8 ºC. A possible reason for 1998 to behave in a slightly different manner (1998 had a MAT value of about 28.1ºC at onset) was because it was the warmest year in the last decade. In 1998 the temperature condition necessary for the disease onset seemed to have been met in the first 4week month itself and what had been required was the moisture. Also to be noted from Figure 3.5 is the fact that although the number of dengue cases had been decreasing with the decrease in temperature and rainfall, the number had been fairly high during the first few 4week months in 1998. Possibly the higher temperatures in the later period of 1997 may have been influencing the dengue incidence in the early period of 1998, in addition to the 1998 temperatures themselves. Although the number of reported dengue cases in the early period was low compared to 1998, influence of the later period temperature of the previous year was also visible in 2001 and 2003. Warmer conditions in the later period of a year may trigger warmer conditions in the early period of the following year, more probable with El Niño and El Niño+1 years (Enfield and Alfaro, 1999), and hence an epidemic started in the later part of such a year can extend to the following year as higher temperatures can influence the disease prolongation. This scenario is more favoured during El Niño episodes (El Niño and El Niño+1 events). One of the strongest El Niño episodes during the last century was in 1997/1998 and the first El Niño episode in the present century, though weaker than the one in 1997/1998, was in 2002/2003.

Figure 3.11 illustrates the monthly variability of reported cases and MAT for Barbados. In Barbados average MAT at onset was about 26.6ºC for 1995, 1996, 1997, 1998, and 1999. The deviations of the MAT values at onset of the disease from the average, for individual years, were within 0.4 ºC (table 3.5). It is interesting to note from figures 3.6 and 3.11, that in 1996 MAT values in Barbados are less than or barely at 26.6ºC and dengue incidence was very low, though the rainfall had been comparable with other years.

This observation support the earlier view put forward that the association of the disease with temperature is stronger.

Figure 3.12 illustrates the monthly variability of reported cases and MAT for Jamaica. The MAT value at onset was about 28.2 ºC for 1995 and 1998 (table 3.5). In 1995 and 1998 there were fairly strong outbreaks of dengue in Jamaica, as mentioned earlier. It is seen from figures 3.7 to 3.12 that MAT has the feature that it increases with time and its pattern follows that of dengue cases better than that of the 4week monthly/calendar monthly temperature. Based on the results seen, MAT appears to be another but simple and a better parameter that is suitable to predict the potential for the onset and strengthening of the disease.

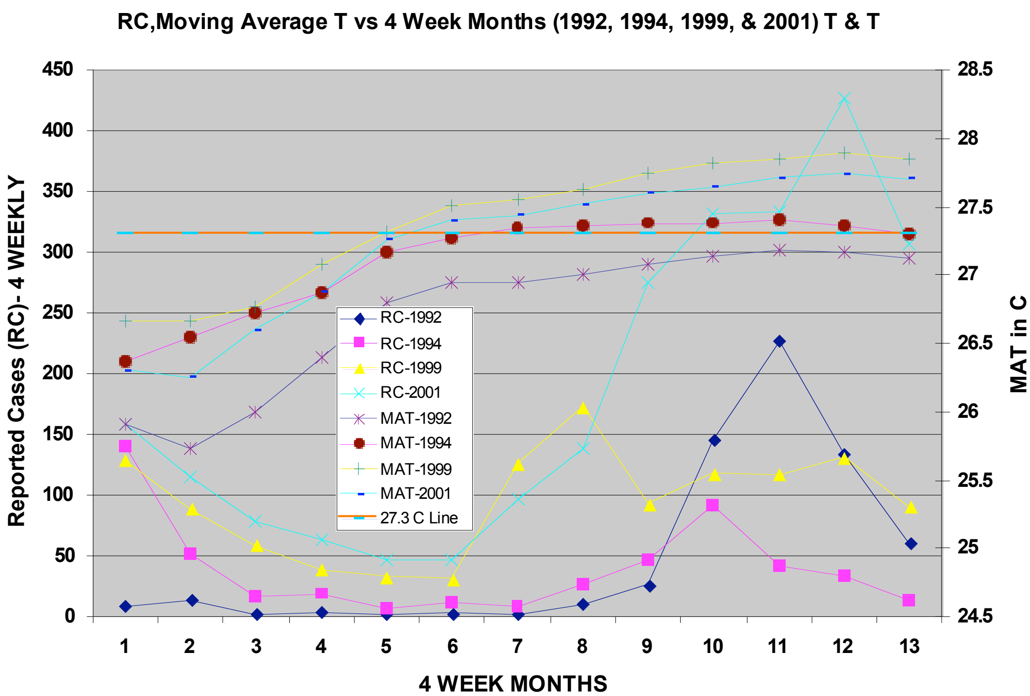


Fig. 3.7: RC, Moving average T vs 4 week months (1992, 1994, 1999 & 2001) T & T

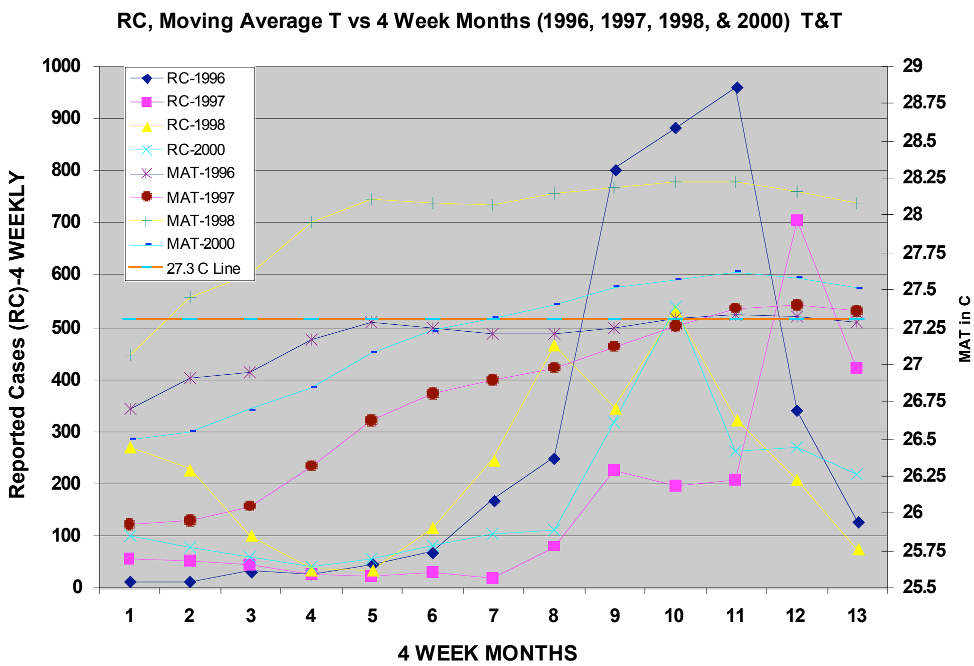


Fig. 3.8: RC, Moving average T vs 4 week months (1996, 1997, 1998 & 2000) T & T

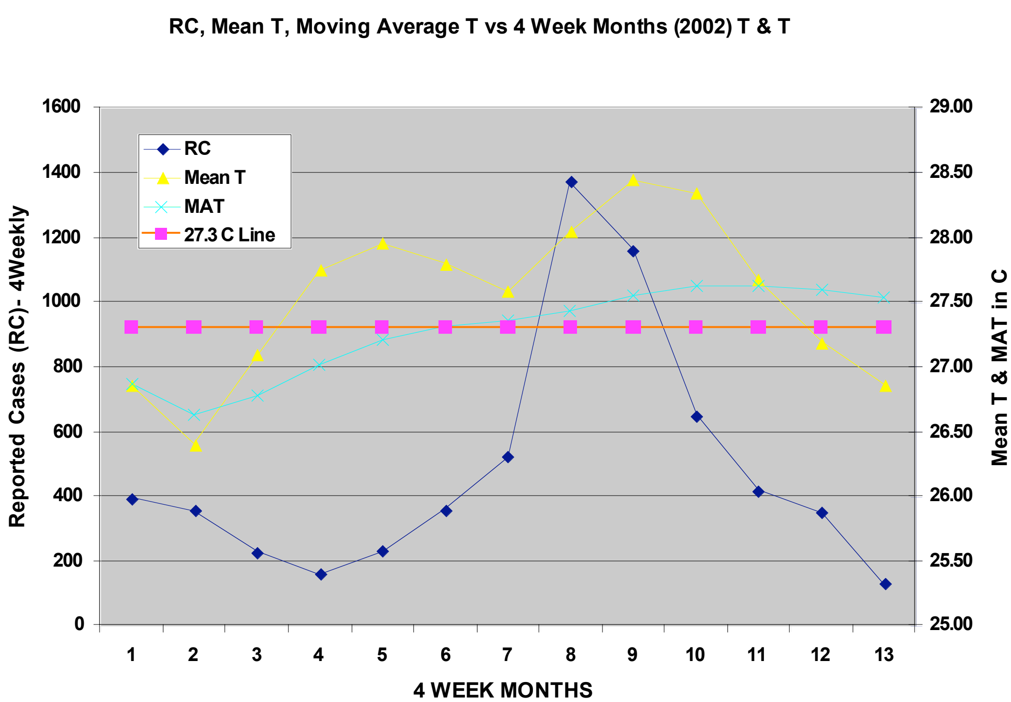


Fig. 3.9: RC, Mean T Moving average T vs 4 week months (2002) T & T

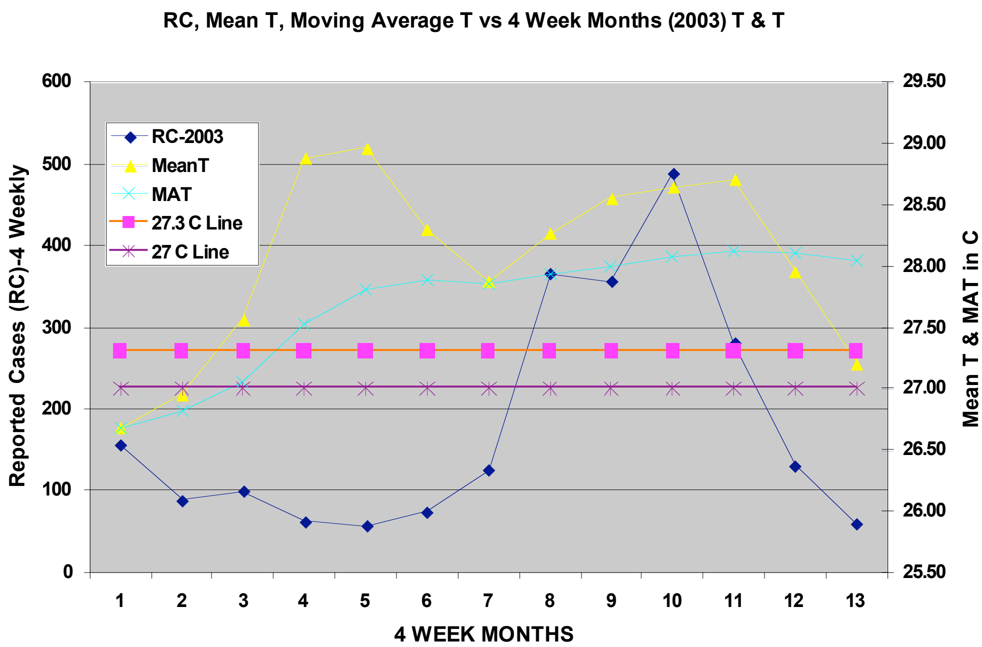


Fig. 3.10: RC, Mean T, Moving average T vs 4 week months (2003) T & T

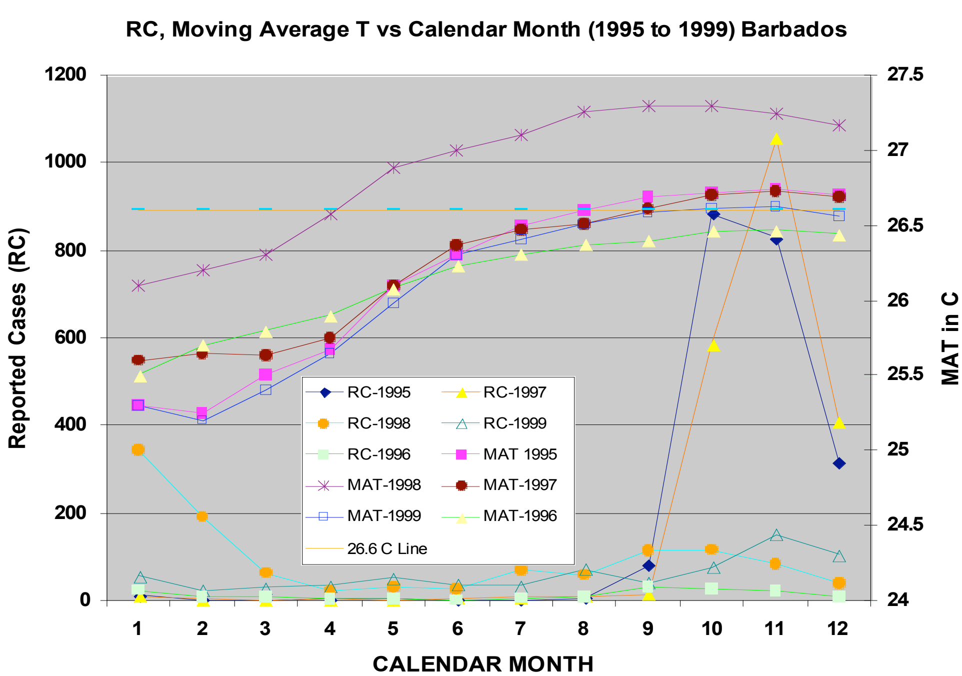


Fig. 3.11: RC, Moving average T vs calendar month (1995 - 1999) Barbados

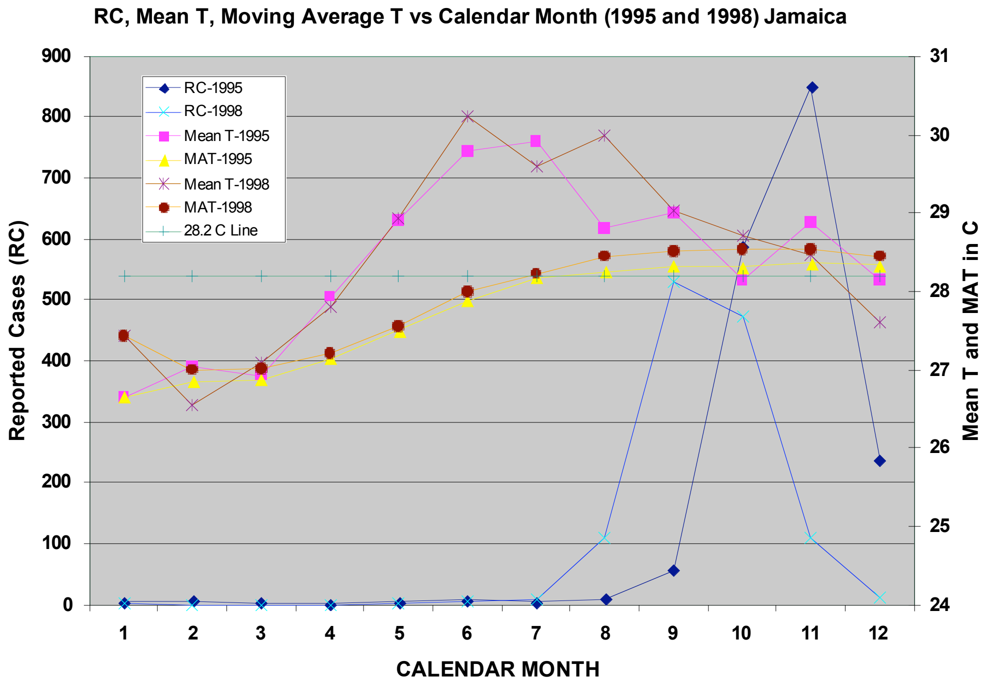


Fig. 3.12: RC, Mean T, Moving average T vs calendar month (1995 - 1998) Jamaica

Country	Year	Onset Time*	Statistical Lag*
Trinidad and Tobago	1992	7th	6
	1994	7th	4 to 5
	1996	4th	5
	1997	7th	6 to 7
	1998	4th to 5th	4 (Not significant)
	1999	6th	3 to 4
	2000	4th	4
	2001	6th	4 to 6
	2002	4th	7
	2003	4th to 5th	3 and 8; 3 acceptable while 8 is very significant

*Onset time and lag are in 4 week months.

Table 3.3. Results for the disease onset time measured from the beginning of a year, statistically observed lag in Trinidad and Tobago.

Country	Year	Onset Time*	Statistical Lag*
Barbados	1995	7th to 8th	5
	1996	7th to 8th (Not significant)	Not significant
	1997	5th to 9th	5
	1998	4th to 6th	3
	1999	6th to 9th	5
Jamaica	1995	8th	4
	1998	7th	3

*Onset time and lag are in calendar months.

Table 3.4: Results for the disease onset time measured from the beginning of a year, statistically observed lag in Barbados and Jamaica.

Country	Year	Early Peak Temperature (Tep) in °C	Temperature at Onset in °C	Lapse Time Between Early Peak and Onset	MAT in °C
Trinidad and Tobago	1992	28.3	27.0	2-4week periods	27.0
	1994	28.4	27.8	2-4week periods	27.3
	1996	27.8	27.8	< 4 weeks	27.2
	1997	27.8	27.5	2-4week periods	27.5
	1998	29.0	28.7	≤ 4 weeks	28.1
	1999	28.5	28.5	< 4 weeks	27.5
	2000	28.0	27.2	< 4 weeks	26.9
	2001	28.8	28.1	1-4week periods	27.4
	2002	28.0	27.7	< 4 weeks	27.0
	2003	29.0	28.9	< 4 weeks	27.5
Barbados	1995	27.7	27.2	1 month	26.6
(Small DF Peak)	1996	27.0	26.8	2 months	26.4
	1997	27.7	27.4	2 to 3 months	26.6
	1998	28.1	27.6	1 month	27.0
	1999	27.8	27.1	1 month	26.6
Jamaica	1995	29.9	28.8	1 month	28.2
	1998	30.2	29.6	1 month	28.2

Table 3.5: Results for the estimated early peak in temperature (Tep), temperature at onset, lapse time between early peak and onset, and MAT at onset in Trinidad and Tobago, Barbados and Jamaica

3.2.3 Conclusions

The results obtained in the retrospective component of the project are encouraging.

The results depicted the following:

- A well defined seasonality of the epidemics.
- Association of the disease with climate, especially through temperature and during El Niño episodes (El Niño and El Niño+1 events). This feature was more pronounced in Trinidad and Tobago data.
- Indices linked to temperature (Tep and lapse time to disease onset, country's average disease onset temperature , and average MAT value at disease onset) to predict the onset of dengue. Perhaps, the average MAT values for the different countries at onset could be used as thresholds to gauge the time that the onset and strengthening of the disease start as MAT values in any given year lead to an ascending sequence of numbers, the MAT values in different years approach the respective average MAT values at dengue onset, and the strengthening is immediately after the approach of the average MAT.
- During years with warmer early periods such as 1998, 2002 and 2003 in Trinidad, 1998 in Barbados, 1998 in Jamaica, the onset occurred early. Further in such years the onset of the disease is immediately after the decay of the previous epidemic.

Seasonality, association with El Niño episodes, early onset of the disease in years with warmer early periods, time of Tep along with the average lapse time to disease onset, estimated country's average onset temperature, and the estimated average MAT values at disease onset for the three countries are useful tools in designing warning systems and formulating suitable adaptation strategies. Based on the seasonality, the possibility of outbreaks exists in the 2nd half of any year. The epidemics occur earlier if the early part of the year is warmer, which is more likely to happen in an El Niño+1 year as the later half of an El Niño year is warmer and it can influence the temperature field in the next year (Enfield and Alfaro, 1999). In situations where temperature can be forecasted with some degree of certainty, indices based on temperature can be practical and useful in any prediction scheme. It should be remembered that some moisture is required for mosquito breeding, although the quantity of moisture required was not assessed. Wet breeding places are generally present in the environment around households. Most common ones are stagnant water pockets after rainfall, unattended/uncovered domestic water storage containers, discarded tires and containers, and wet flower pots. Household environments are normally, not totally dry.

The observed statistical lag needs some attention. The lag was easily visible when one concentrated on the temperature and dengue peaks, for example in figures 3.5 and 3.6. These lags are of the order of a few 4week months/calendar months. It is a known fact that the life time of a mosquito is of the order of a few weeks, and including the time for transmission, the time period that may elapse to disease incidence since hatching of the eggs may be of the order of a month. But it may also take a couple of months for multiple transmissions to become an epidemic or for an increase in the disease to be noted. Based on the data used the lags observed which are greater than > a few 4week months/calendar months are significant. As mentioned before, similar lags have been observed by Wegbreit (1997). The long lag may be explained in terms of multiple transmissions needed to compound into an epidemic or for the disease to be noted. Alternatively another plausible way of explaining the observed lag and the relevance of MAT is to consider the net heat build up (net accumulation of heat) in the mosquito breeding environments over time. Perhaps, it may be the net heat accumulation that conditions the environment suitable to the onset of the disease and may not be the temperature directly. A similar view has been hinted by Wegbreit, 1997. The net heat build up is dependent on thermal radiation (solar radiation) and other parameters such as rainfall, heat losses and cooling in the nights. Therefore the net heat build up is a slow process and lag of the order of a few 4week months/calendar months are possible and the lag can vary from one year to the other. However, the process has to be associated with a temporal increase in a temperature index. The MAT that has been deduced and which is increasing with time may be that temperature index.

A few important limitations have to be stated, which are as follows:

Firstly, the indices formulated in this work can vary from one country to another and depended on the temperature field. If the temperature fields were similar, indices could be similar. On the other hand if the temperature fields were different, as with Trinidad and Barbados or Jamaica, the indices would be different. Also the data set for temperature have to be continuous, at least for a year, and reliable. So to apply the schemes outlined in this work to gauge the potential for the onset of dengue in a given country one has to make sure that a reliable and a continuous set of data for temperature exists in that country. Secondly, the schemes presented in this paper do not include the influence of higher temperatures in the later part of some years on the incidence of the disease in the early part of the next year. Examples are 1997/98, 2000/01, 2001/02, and 2002/03 in Trinidad. It is hoped to look at this issue under another assignment by optimizing the lags observed over several years when more data becomes available. Thirdly and most importantly, to make the schemes more versatile, the viability of the indices has to be examined in relation to mosquito dynamics and virus replication rates using epidemiological data. This aspect was outside the scope of the present study.

3.2.4 Future work

- Attempt to fine tune the indices using Trinidad weekly data.
- Attempt to develop a dengue forecast model for the Caribbean.
- Attempt to investigate reasons, if any, for the increase in dengue incidence from north to south in the Caribbean.

3.3 Prospective Study

3.3.1 Description of scientific methods and data

The Prospective Study, which looked at the relationship between climate change and dengue fever in real time, was initiated in early 2003. At first, four countries were selected as sites in which these studies were to be conducted; soon after, when we experienced some trouble with the Barbados data, another country, St Vincent and the Grenadines, was added to the group which were then:

- Jamaica in the north with some 2.5 m inhabitants, an example of the "Greater Antilles" with occasional DF epidemics. Six zones of the Kingston St Andrew area were selected for the vector studies.
- Trinidad and Tobago, in the Southern Caribbean with a history of significant DF. The area of Curepe in St George Central was selected for the Vector studies as well as the meteorological data collection. DF and other vector indices were collected from the larger Trinidad and Tobago landscape.
- Barbados in the Eastern Caribbean, a medium-sized country, with recent DF endemicity. Three surveillance areas were selected for the vector studies:- Blades Hill in St Philip, Six Mens in Maurice Byer area and Carrington Village in the Sir Winston Scott area.. DF data would be accessed from the national figures. It soon became clear that the Barbados data were inadequate, and thus, the St Vincent site was added to the study.
- St Kitts/Nevis (SKN) in the Eastern Caribbean, a micro state of just over 40,000 population. Because of the relative small size of the islands, and that sampling of the island could be reported on a monthly basis, the whole island of St Kitts was utilized as our study site.
- St Vincent and the Grenadines (SVG), another micro state with DF epidemics. The area of Montrose in the capital, Kingstown was selected for the vector studies, while the climate data were collected at the nearby meteorology centre at the Joshua airport.

Agreement was made with the national epidemiologists in these countries to supply data through CAREC epidemiology unit on a regular and faithful timely manner for the country as a whole and for a selected pilot site in country for:

- DF cases on a monthly basis
- Breteau indices and House indices of the dengue vector (See Box 2 below), Ae aegypti, in the designated study areas – with a minimum of 100 residences to be examined per month for a whole 12 month period.

- Monthly climate data were also to be obtained from the local meteorological office for the study area. These data would be supplied directly to the AIACC research office.
- During the 12 month study, it was necessary for the AIACC researcher to visit most the study sites to encourage the data collection and to ensure the integrity of the data that were being sent to the study centre at CAREC.

At the end of the 12 month period the data were assembled and examined for any patterns of association, and analyzed for evidence which seemed to show climate-related variation in DF case numbers and vector indices.

Box 2. Definitions

The BI (Breteau index) is the defined as the total number of Ae aegypti - positive containers detected per 100 homes inspected.

The HI is the Household Index defined as the total number of homes found to be positive for Ae aegypti breeding per 100 homes inspected.

The Container Index (CI) is the total number of Aedes Aegypti positive containers as a percentage of the total number of wet containers examined.

3.3.2 Results

3.3.2.1 Vector surveillance data

St Vincent and the Grenadines

Data on DF vector, *Aedes aegypti* and surveillance, and climate indicators are presented in Table 3.6 and Figure 3.13 for St Vincent and the Grenadines (SVG) for the year 2003 – 2004. The data showed only minor fluctuations of Ae aegypti house indices (HI) and breteau indices (BI) with varying precipitation. Dry seasonal weather (Feb.to May), coincided with low vector indices – HI, 9 to 22%; BI, 13 to 33%. Wetter season conditions that prevailed in June to November coincided with HI of 17 to 22% and BI of 31 to 55%. At the same time, relative humidities did not vary significantly year round (70 to 77%).

With only six cases of DF recorded for the whole period, it was not possible to make a statistically significant association of DF transmission patterns and climate features for this year in SVG. This low occurrence of DF locally may have been the effect of reduced sensitivity to DF 3 virus, this being the second year it was in circulation, despite the abundance of vectors in the local environment.

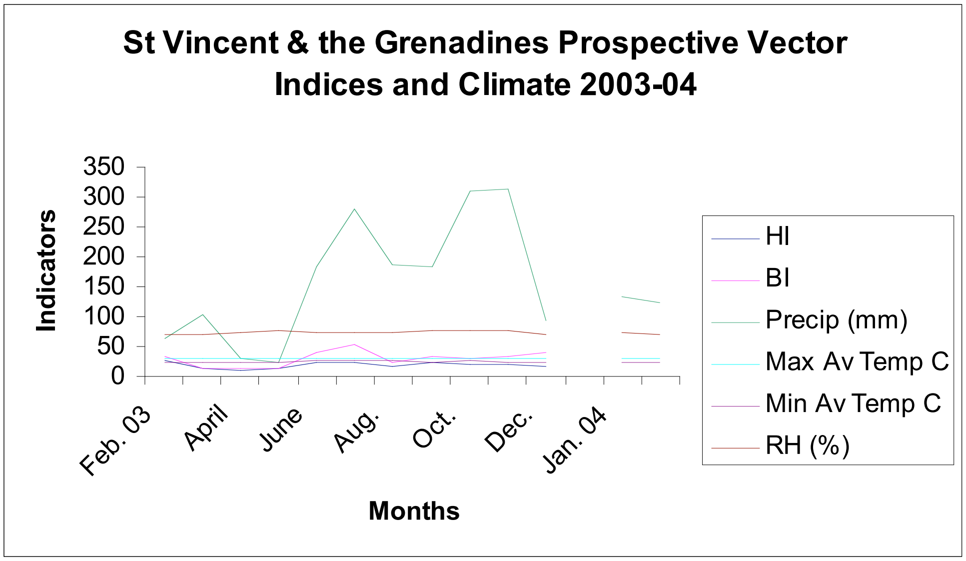


Fig. 3.13: St. Vincent and the Grenadines-Prospective vector indices and climate

Month	HI	BI	Precip	Max Av	Min Av	RH	DF Cases
Feb. 03	26.98	33.33	62.2	29.5	24.2	71	0
March	11.72	13.28	104	29.1	23.1	70	1
April	9.52	14.29	30.25	29.2	23.4	72	0
May	12.1	14.52	21.9	30.2	24.9	76	0
June	22.4	39.2	182.8	30.4	25.6	73	0
July	23.8	55	280.5	30.3	25.7	72	1
Aug.	17.19	25	187.6	30.9	25.1	72	1
Sept.	21.71	33.33	183.7	30.8	24.7	77	2
Oct.	20.63	30.95	311	31.25	25.3	76	1
Nov.	21.09	34.38	313.45	30.2	24	76	0
Dec.	15.78	38.34	94.8	29.7	24	71	0
Jan. 04			133.6	29.5	23.7	72	
Feb.			123.6	29.2	23.1	70	

Precip.:mm
HI (125 premise)
Climate data taken at ET Joshua Airport, Kingstown

Table 3.6: St. Vincent and the Grenadines-Prospective vector indices and climate

St Kitts and Nevis

Vector data for St Kitts/Nevis showed some interesting patterns (Table 3.6). There was a bimodal increase in house and breteau indices with climate. There were increases in HI and BI in the months of

May to June coinciding with gentle increases in mean monthly ambient temperatures; also, there were increases in November – December with significant increases in precipitation (Fig. 3.14)

Month	HI	CI	BI	Precip.	Temp.	DF Cases
Jan	4.4	12.4	11.3	1.32	26.6	2
Feb	4.9	6.8	6.5	1.89	26.4	0
March	1.1	5	3.1	0.85	26.6	0
April	2.7	5.4	5.5	2.19	27.3	0
May	5.9	7.9	14.8	0.9	27.8	0
June	1.9	14.3	13.8	3.07	28.2	0
July	6.2	13.3	10	1.07	28.7	0
August	8.2	5.4	6	1.42	29	0
Sept.	6.6	6.8	6	1.62	29.4	0
Oct.	7	6.7	10	5.49	28.7	0
Nov.	8.2	21	11	8.78	27	0
Dec.	9.3	13	11	7.3	26.6	0

Precipitation in In.

Climate data taken at the Robert Bradshaw Airport, Basseterre

Table 3.7: St. Kitts vector indices and climate for 2003

In St Kitts, the peak of the early wet season (in June) coincided with the peak of the container index and preceded the house index by one month (Table 3.7). The latter, major, wet season rains of Oct., Nov. and December coincided with the highest container and house indices of 7 to 9.3% (HI) and 6.7 to 21% (CI), but not of the BIs which remained around 10 to 11%. While ambient temperatures reached their annual peak of 27 to 28° C in June – at the same time of the peak in BIs, these temperatures also lasted down to October at the time of the second (greater) wet season, when BIs were on their wane. Apart from the two reported DF cases of January, there were no further cases reported on the island for 2003. It is likely that both wetter conditions and the warmer period of June – Oct, accounted for the increased HIs and CIs and thus the potential for DF transmission. Here also, DF transmission may have been reduced by the absence of susceptible human hosts due to an acquired (herd) immunity.

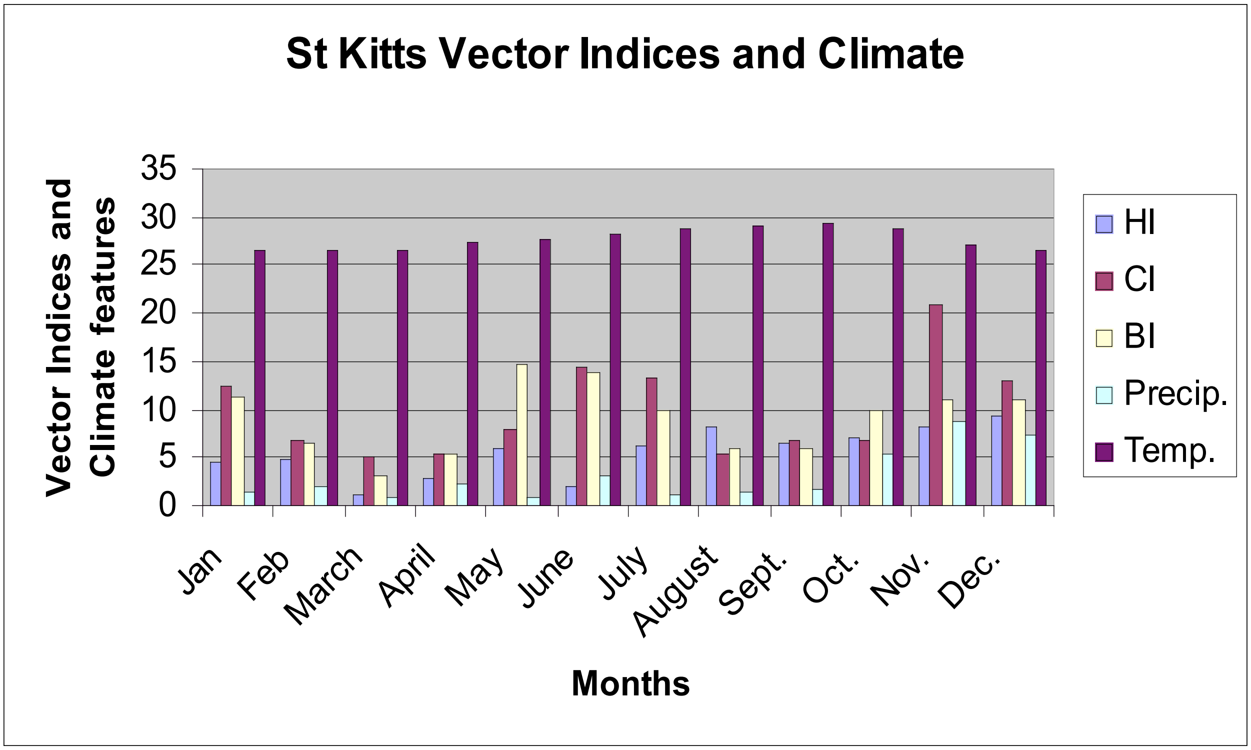


Fig. 3.14: Vector indices and climate indicators in St Kitts, 2003

Trinidad and Tobago

Data from the Curepe area of north0ern Trinidad showed some climate-related effects on *Ae aegypti* production (Figure 3.15). The earlier drier months (Jan to May) were characterized by having mean HI of 9.3 to 8.3 %. The onset of the wet season in June however, was accompanied by significant increases in the HI up to 20 % (July), with a range of 14.3 % (June) to 14.9 % (December).

Table 3.8 shows from the Trinidad and Tobago prospective data, for 2002 and 2003, there is seasonal correlation of seasonally increased precipitation and dengue fever transmission. Although the 2002 rainfall started in April and there was already an increase up to 70% positive rate for ovitrap breeding, it was a three month lag before there were significant increases in DF cases, up to 1407 cases in July. Breteau indices increased up to about 30, and were correlated with increases in DF cases the following month (Figures 3.15 and 3.16). In 2003, there was a later onset of the wet season in June, but there was an immediate increase of the BIs, which was followed two months with increase in reported cases. As the rainfall continued right down to the end of the year, so did the DF transmission. Interestingly, the county mean *Aedes* house indices almost doubled between the low rainfall period at the beginning of the Year (9.3%), and the middle of the year July (20%), when the rainfall really was at its height (Table 3.9). In 2003, increases in DF transmission with rainfall really correlated with the upsurge of the wet season (Figures. 3.17 and 3.19), and despite a slight drop in rainfall, transmission continued to the end of 2003. Temperatures were of significance. All temperatures were within the range acceptable to *Ae aegypti* for development, 22 – 32 °C (Focks, 1995); however, maximum or minimum temperatures of around 24°C in May, just preceded by 1 month lag, significant increases in DF cases. DF transmission continued right to the end of the year when max temperatures continued to be optimal at 31° C.

The difference in case numbers for 2002 (6314) and 2003 (2340), could not be easily explained by climatic variation, since the patterns were much the same for the two years under review. Other factors such as enhanced vector management and increased immunity to DF 3 by the community may have been responsible.

				<u>2002</u>				
MONTH	**MIN TEMP**	**MAX TEMP**	**PRECIP**	**%trap +**	**BI**	**DF CASES**		
						St G. C.	**T&T**	**T&T (monthly)**
Jan	22.9	30.9	144.9	91.31	21		394	394
Feb	21.7	31.1	23.3	78.9	20		748	354
March	22.8	31.6	57.7	49.8	21		1033	285
April	23.4	31.9	216	71.45	22		1166	133
May	24.6	31.5	144.3	77.31	29		1452	286
June	24.4	31	245.4	74.78	32		1812	360
July	24.3	31.3	232.9	87.64	30		3219	1407
Aug	24.1	32.3	144.4	87.1	35		4503	1284
Sept.	24.1	33	55.5	85.04	38		5322	819
Oct.	23.8	32.2	214.4	78.6	40		5785	463
Nov.	23.4	31	406.1	83.32	40		6185	400
Dec.	22.7	31.1	43.5	97.8	29		6314	129
Total						384	6314	
			<u>2003</u>					
Jan			29.7	90.93	27	2	107	
Feb.			41.7	81.22	22	7	196	
March			7.4	84.32	23	8	283	
April			3.5	66.79	24	12	374	
May			41.5	67.99	29	13	446	
June			257.7	81.85	32	14	516	
July			193.1	90.07	33	15	719	
Aug.			215.7	87.5	35	20	996	
Sept.			151.3	91.17	38	23	1439	
Oct.			90.4	80.21	40	34	2122	
Nov.			200.5	86.57	44	37	2269	
Dec.			194.6	82.51	30	37	2340	
Total						37	2340	

Table 3.8: Curepe (St. George, C. Trinidad), Climate, vector Indices and dengue cases, 2002-2003

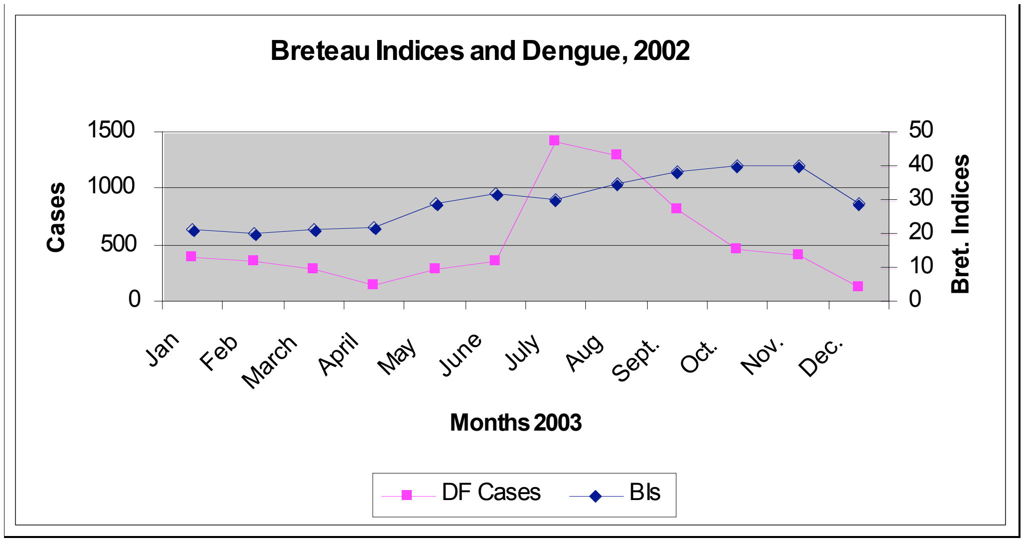


Fig. 3.15: Breteau indices and dengue fever in Trinidad and Tobago

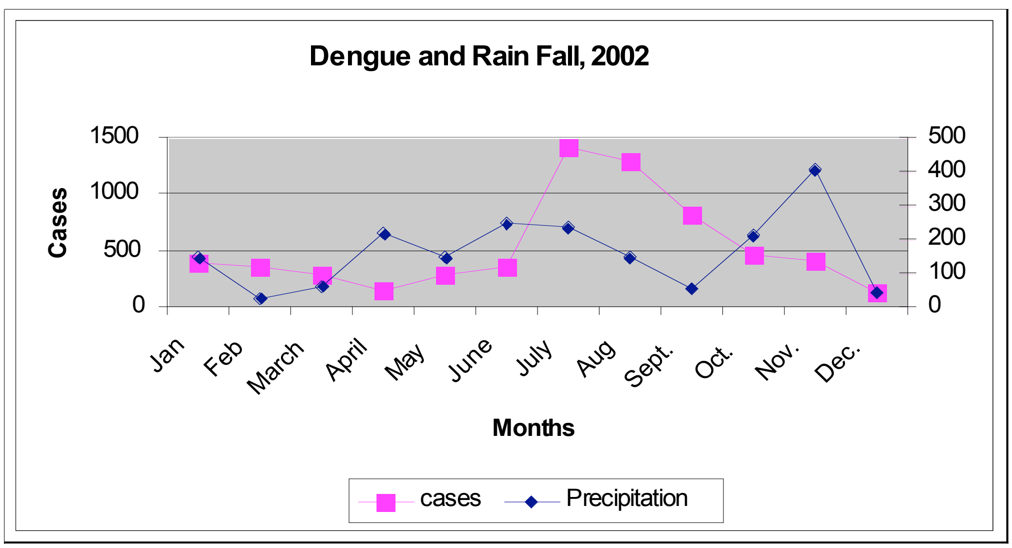


Fig. 3.16: Dengue and precipitation, Trinidad and Tobago 2002-2003.

County			Months, 2003									
	J	**F**	**M**	**A**	**M**	**JUN**	**JUL**	**AUG**	**S**	**O**	**N**	**D**
SGW	4.4	4.4	4.8	6.5	7.1	13.6	26.3	23.5	11.1	32.8	24.8	16.5
SGC	9.4	9.4	8.4	6.4	6.7	8.6	12.5	15.7	17.1	17.4	16.4	16
SGE	13.8	8.4	5.5	6.2	6.2	10	15.6	19.2	15.7	19.1	16.8	16.6
SA/D	6.1	5.7	9.6	3.7	10.8	11.7	17.1	10.8	12.8	11	14	10.6
CAR	5.4	5.6	9.4	3	6.3	11.8	13.1	7.9	10.9	9.7	12	6
VIW	5.4	11.8	12	11.2	9.5	20	19.1	11.2	12.8	17.6	14.1	15.3
VIE	10.4	12.3	6.9	6.3	8.4	9.9	20.7	19.5	14.3	12.2	13.6	12.6
STP	12.2	14.3	11.2	14.7	10.2	25	30.1	24.7	19.2	18	24.3	17.7
N/M	13.5	17.8	19.2	18.4	12.8	19.8	28.1	18.6	20.3	18	19.3	22.4
T/DAD	9.3	9.4	9.4	8.5	8.3	14.3	20	16.9	14.5	15.9	17.3	14.9
RF mm	29.7	41.7	7.4	3.5	41.5	257.7	193	215.7	151.3	90.4	200.5	194.6

Table 3.9: County Aedes Indices by month 2003

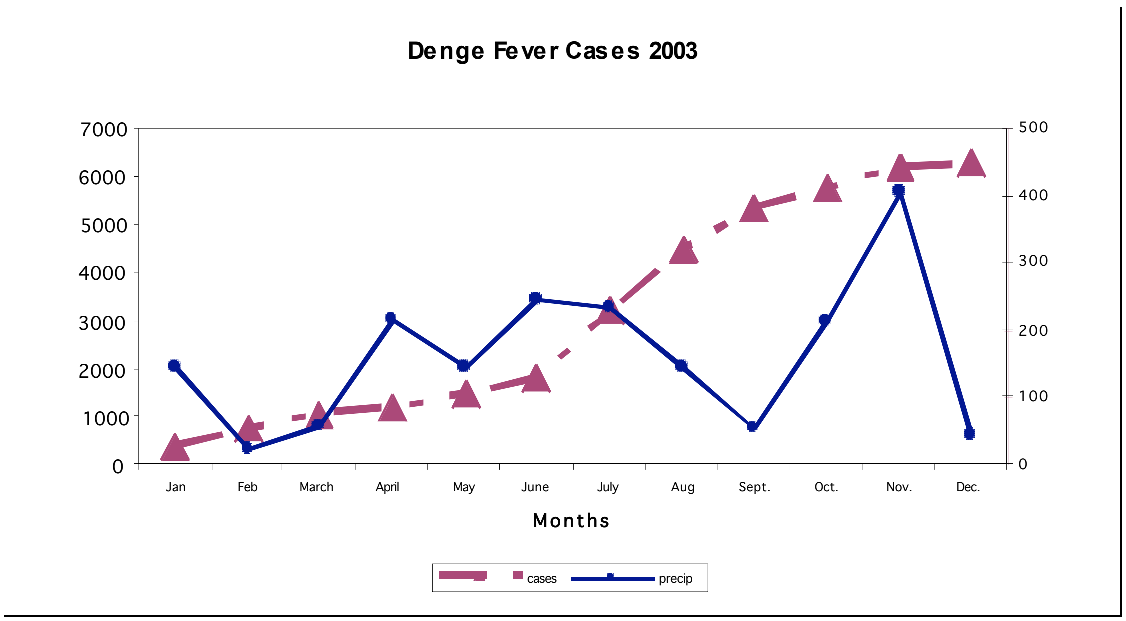


Fig. 3.17: Dengue fever cases and precipitation in Trinidad, 2003

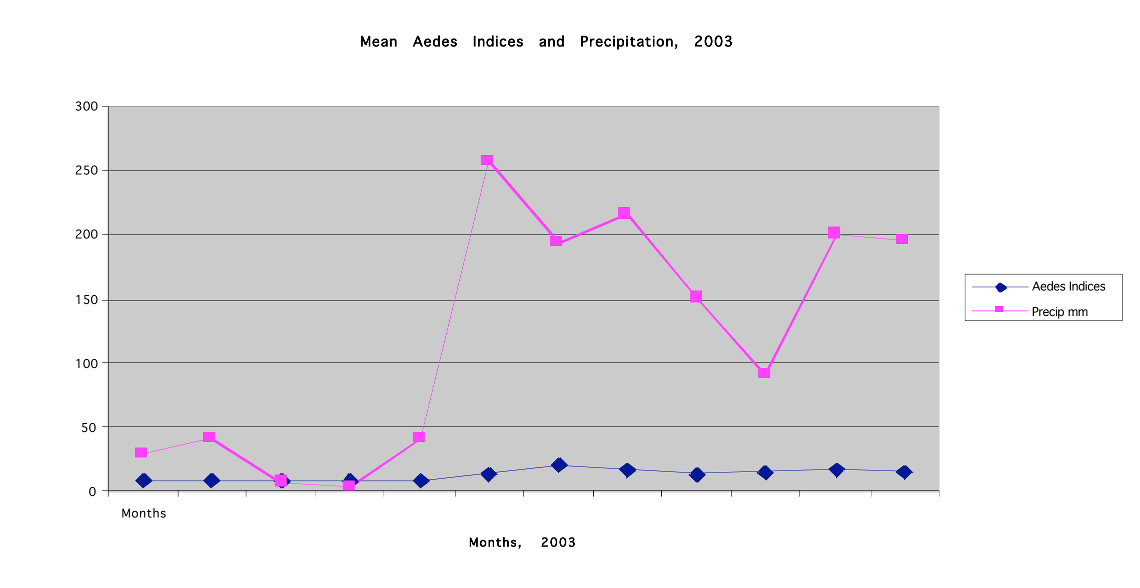


Fig. 3.18: Mean Aedes Indices and precipitation in Trindad and Tobago, 2003

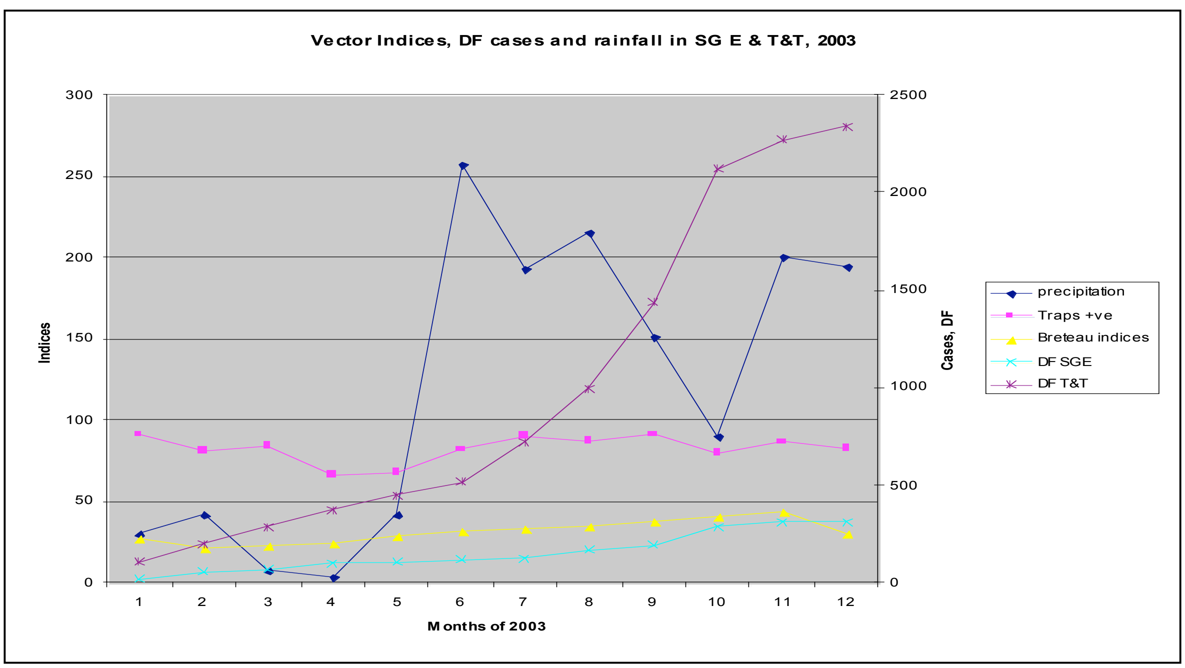


Fig. 3.19: Vector Indices, dengue fever cases and rainfall in SG County and Trinidad and Tobago, 2003

Jamaica

The variation of precipitation in zones of Kingston, Jamaica did not significantly impact on the breteau indices of *Aedes aegypti*, the DF vector in 2003 – 2004. There was no sign of significantly enhanced breeding and vector production correlating with the increased rainfall and potentially increased breeding habitats. Vector breeding seemed to continue unabated year round. This suggested that water storage could have facilitated vector production in all seasons of the year.

In the Jamaican situation, there were two peaks of BIs – April to May and September to November 2003, (Table 3.10, Figures 3.20 & 3.21). The small number of cases in 2003 could not be used to show statistical correlations of precipitation and BIs or DF cases. Zone 4 appeared to be the area with highest Breteau indices, especially in the period April to November, falling to single digit indices here and in all other zones of the corporate area (Table 3.10). At the same time, there was no evidence of a climate-related DF transmission in these six zones of Kingston and St Andrew: this was probably due to the low level of DF transmission nationally.

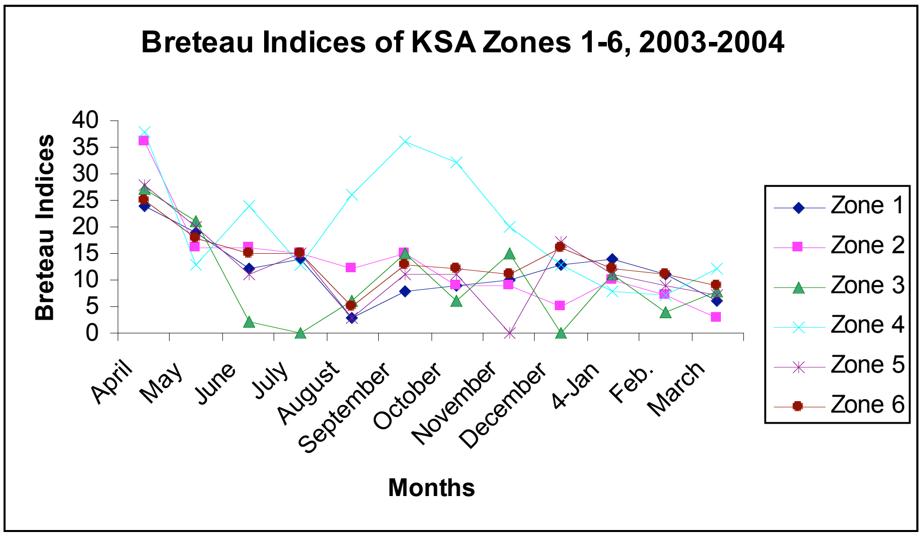


Fig. 3.20: Breteau Indices of KSA Zones 1-6, 2003-2004

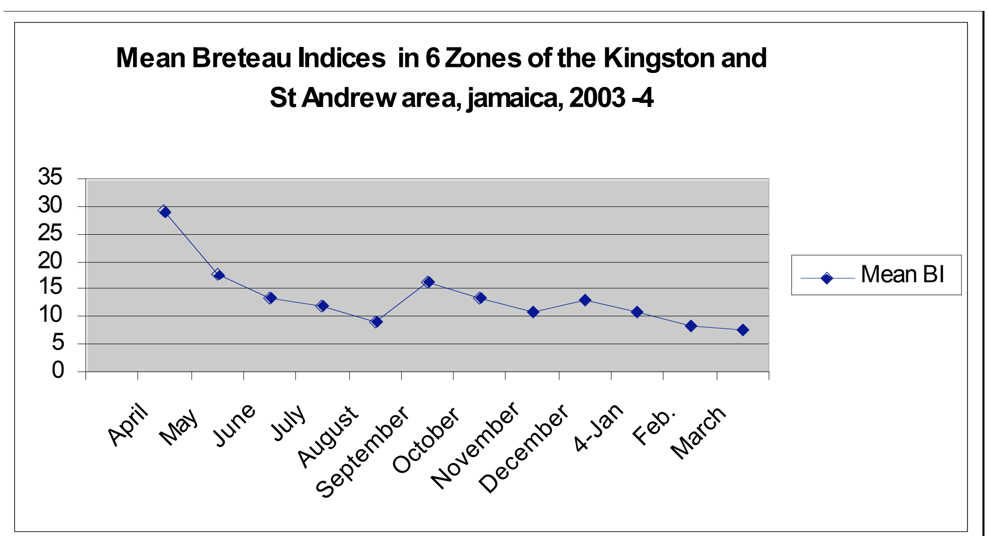


Fig. 3.21: Mean Breteau Indices in 6 zones of Kingston and St. Andrew Area

Kingston and St Andrew Divisions 1 - 6

Months	**BIs in KSA Divs 1 - 6**						**Mean**
2003	**1**	**2**	**3**	**4**	**5**	**6**	**Index**
April	24	36	27	38	28	25	29.2
May	19	16	21	13	20	18	17.8
June	12	16	2	24	11	15	13.3
July	14	15	0	13	15	15	12
August	3	12	6	26	3	5	9.2
September	8	15	15	36	11	13	16.3
October	9	9	6	32	11	12	13.2
November	10	9	15	20	0	11	10.8
December	13	5	-	13	17	16	13
4-Jan	14	10	11	8	11	12	11
Feb.	11	7	4	7	9	11	8.2
March	6	3	8	12	7	9	7.5

Table 3.10: Jamaica Breteau Indices, 2003

Barbados

The Barbados vector data (Table 3.11), reported to us by the Ministry of Health Vector Control Unit, appear to be quite questionable. While the epidemiological data in Table 3.12 show that there was transmission occurring, with over 700 cases reported, Table 3.11 shows that there was inadequate measurement and reporting of the *Aedes* indices. The consistently low HIs, CIs and BIs of 0 – 1%, indicate that there was something wrong – except that the study site was so different from the rest of Barbados, that few if any mosquitoes were being produced here as opposed to the rest of the country. The traditional DF season is demonstrated with 465 0f 728 (64%) of the cases occurring in the last quarter (wettest period) of the year with significant numbers of cases extending into January.

Months		**Indices**	
	House	**Container**	**Breteau**
April	1	0.2	1
May	1	0.5	1
June	2	1.1	3
July	ND	ND	ND
August	0	0	0
September	1	1	1
October	0	0	0

The study was discontinued due to absence of adequate data

ND = No Data

There were 763 cases reported on Barbados for 2003.

Table 3.11: Barbados Vector Indices in the study area, 2003

Month	Cases
Jan	94
Feb	21
March	31
April	16
May	13
June	17
July	8
Aug.	31
Sept.	42
Oct.	76
Nov.	230
Dec.	159
Total	728

Table 3.12: Barbados national dengue fever cases reported for 2003

Generally two major patterns of DF occurrence could be discerned:

- **A seasonal effec**t – with the vast majority of the DF cases occurring in the wet season lasting in the Caribbean from September to November in most cases. This is likely due to the increase in habitats producing Aedes aegypti due to the increased abundance of water-holding containers. After a lag of about 4-6 weeks after the onset of the rainy season, there is an increase of biting mosquito activity, followed about 4 weeks later by increased numbers of cases. There are two conditions however: that there is a human host population that is sensitive to a DF virus and that there is a virus in circulation.
- **The temperature effect**. This is discussed more fully in the chapter on retrospective studies, in the context of the Moving Average Temperature (MAT). This could well be understood if one accepts the theories of Hales et al, Rueda et al, Focks et al and Koopman et al (2-5), where it is suggested that elevated temperatures could speed up viral replication and thus facilitate the shortening of the extrinsic incubation period (EIP). Thus small increases in temperature in these warmer periods such as the El Niño year of 2002, may have coincided with or caused the significant increase in virus transmission.

The year 2002 was already the second year of transmission of DF3 virus in most Caribbean countries. By 2003 and 2004, most of the inhabitants had already been exposed to this virus and therefore had become resistant or immune to this virus. Thus, while the data above show in 2003 increased breteau indices and vector abundance with the warmer and wetter periods of the year – September to November – there were no large abundance of DF cases. Thus only part of the condition for virus transmission had been met: the climate conditions of temperature and precipitation were right. However, the host (human) sensitivity had been reduced due to past exposure to this virus (DF3). Of course there would continue to be a few cases due to immigrants and children born or a few persons who missed being infected by DF 3 in previous years. When a new virus type is introduced into the region, it is expected that there would then be a big upsurge in transmission if the climate and other environmental conditions are right for disease transmission.

To a large extent, the climate conditions are always right for some degree of DF transmission in the Caribbean – 20 – 32 C, (Focks, 1995). When warmer months, appropriate precipitation conditions are prevalent. With increased Breteau indices and in the presence of a virus-sensitive population these predispose the population for enhanced DF transmission.

The application of adaptation strategies would therefore have to take into consideration these climate and environmental variabilities as well as the human host situation to make appropriate forecasting of outbreaks and intervention for DF prevention.

3.3.2.2 Limitations of the Study

1. The DF data were supplied by Member Countries to the CAREC, thus timeliness and accuracy of the data were to a large extent dependent on partners within CMCs. It is known that there is gross under reporting and over reporting of cases, depending on the epidemiological situation in countries and in the region. What is important in the DF data supplied to the CAREC is that they show trends in disease transmission, and qualitatively, are of significant value.
2. Generally, CAREC member countries' retrospective vector surveillance data are not available and reported to the CAREC. This may have been due to:-
   - Retrospective vector data are not generally seen to be of value for use in the control program. Thus the data are not stored or even shared despite requests from the CAREC.
   - House Indices are generally only of limited value, and the requests to change to other vector surveillance systems have not been accepted.

The prospective vector data studies reported here for Jamaica, St Kitts/Nevis, St Vincent and the Grenadines and Trinidad and Tobago are useful and show that such Breteau and house indices data may be incorporated with disease surveillance and climate data to attempt to discern trends of association which may prove to have a cause and effect relationship. Unfortunately, the data from Barbados were inadequate and therefore could not be included in our consideration.

3.4 Socioeconomic Study-Vulnerability to Dengue Fever in Jamaica

3.4.1 Description of scientific data and methods

There are certain socioeconomic circumstances, which can modify vulnerability to dengue fever, that could make communities more or less susceptible and these are the issues that have been investigated in this paper. The specific objectives of this paper were to:

1. Examine the generic adaptive capacity or conditions in Jamaica that affect its ability to respond to any crisis.
2. Examine the specific adaptive capacity or conditions in Jamaica that affect its ability to respond to an epidemic of dengue fever.
3. Identify the groups that are vulnerable to dengue fever?
4. Examine the characteristics of the households and individuals that are vulnerable to dengue fever?
5. Examine what modifications can increase resilience?

The UNDP defines a country's generic adaptive capacity as the institutions and environment that would enable it to adapt to a range of stresses including environmental and economic change. A high generic capacity was associated with high levels of income, employment, good existing health and the existence of support networks, all of which were likely to make a society resilient to a variety of stresses (UNDP, 2003). Conversely, low generic adaptive capacities rendered societies less resilient to shocks. Generic adaptive capacity provides the foundation for adaptation. Elements of high adaptive capacity were viewed as having synergies with human development including, for example, institutions for the sustainable use of resources, access to health care, decentralized decision making processes and an established scientific base. Such institutions would be more likely to allow the country to make appropriate responses to weather and climate hazards (UNDP, 2003). Consideration of adaptive capacity should begin with national level assessments as trends at this level would reflect the ability of a country to respond to any shock, and this in turn would have significant implications for its ability to respond to a specific disaster, that is, its specific capacity.

Therefore, the problem was approached at two levels. At the macro level, current economic and social trends in the island were examined and particular emphasis was placed on the manner in which these conditions impacted on the most vulnerable.

In addition, interviews were conducted with those the Heads of those agencies that were responsible for the policy document *Jamaica's First National Communication to the United Nations Framework Convention on Climate Change*, which outlined the concerns of the country in so far as climate change was concerned. They were the National Environmental Planning Agency, The National Meteorological Division and The Office of Disaster Preparedness. The purpose of these interviews was to assess how these organisations interpreted their roles, how prepared they were for the challenges that climate change would bring and what efforts they were making to sensitize the public about climate change and its implications. The activities of these institutions are directed to the sustainable use of resources and so can facilitate appropriate responses to hazards

At the specific level of investigation there were interviews with six officials in key positions in the Ministry of Health. They were the Principal Budget Holder, Medical Officers in the Surveillance Department, the Environmental Health Officer, Chief Public Health Officer and Health Educator. They were seen, not only as key informants but as stakeholders who were being given the opportunity to become involved in the planning stage, to share research results and to use those results for the benefit of the constituents they served. The interviews were therefore seen as for a for bidirectional communication, a mechanism for involvement and sharing. Interviews were also conducted with scientists in the Climate Change Group of the University of the West Indies.

In addition, a local level study was incorporated into the analysis to provide a more comprehensive assessment of the island's vulnerability to dengue fever. An attempt was made to select a community that had been the focus of outbreaks in the past but this was hampered by the fragmentary nature of the medical records. In the absence of complete data the researcher had to see if the data on dengue occurrence in any one year formed a recognizable spatial pattern and based on the pattern, which obtained in 1998, a section of the parish of St. James in the north west of the island was selected. In that parish there was a concentration of cases within the city of Montego Bay and sporadic cases, which followed a permanent stream with associated seasonal streams and gully banks. (Figure 3.22) Three communities were selected along this hydrological feature – Granville/Pitfour, a suburb of the parish capital Montego Bay, Retirement, immediately beyond the boundaries of the urban area and rural John's Hall. A questionnaire was administered to a 10 percent sample of heads of households in the three communities (Table 3.13). The questionnaire solicited information on the socio-economic conditions of the householders, support systems, their knowledge of the disease and cultural practices that might have important implications for the spread of dengue fever.

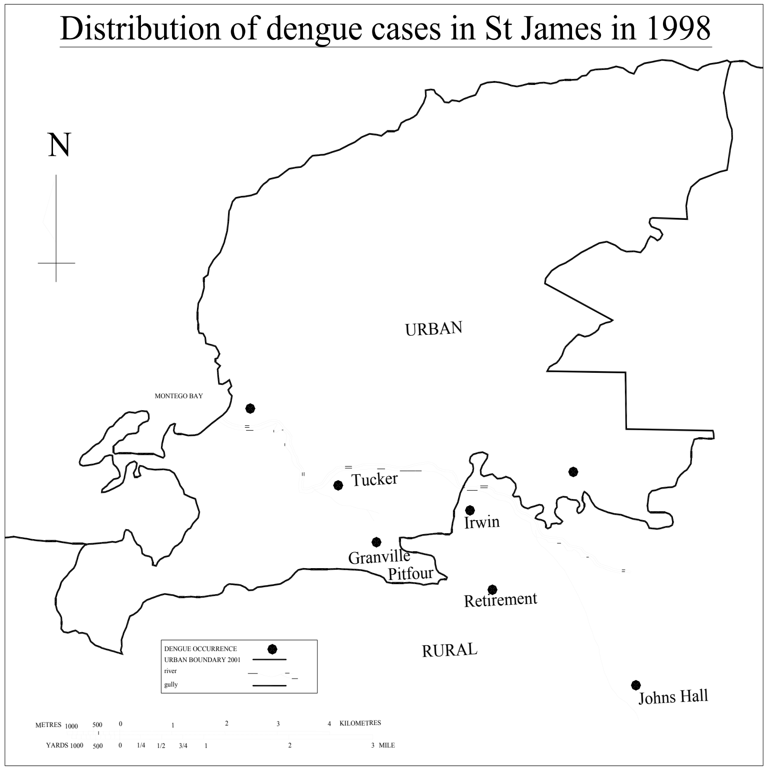


Fig. 3.22: Distribution of dengue cases in St. James, Jamaica, 1998.

Community	# of households	Sample
Granville/Pitfour	1507	151
Retirement	485	49
John's Hall	572	57
Total	2564	257

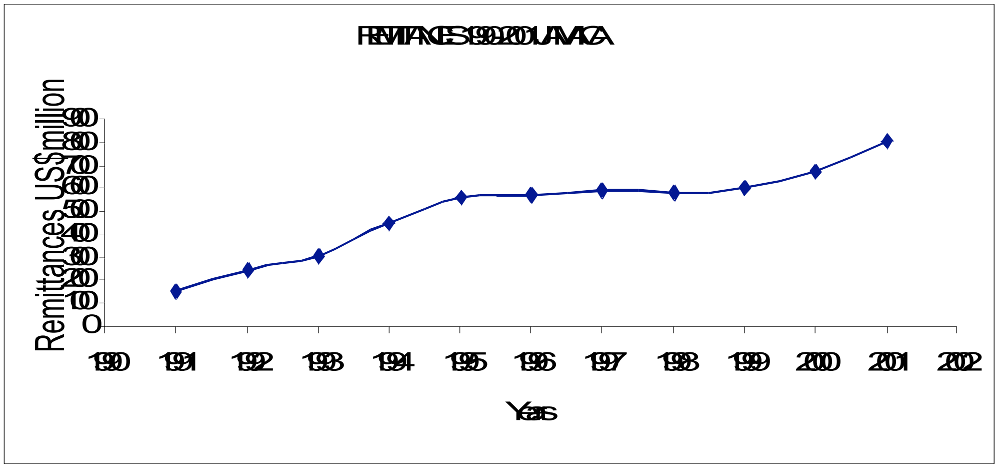
Table 3.13: Sample size

3.4.2 Results

3.4.2.1 Generic capacity

The massive inflow of capital associated with the development of the bauxite/alumina industry in Jamaica in the 1950s served to expand a market that hitherto had been dominated by the export of agricultural products. However, the boom came to an end in the early 1970s and the island experienced a series of crises which forced it to seek the support of the International Monetary Fund (IMF). There is support for the assertion that the adjustment measures recommended by the IMF were felt most keenly by the poor because of job loss, the increases in prices consequent upon devaluation and the removal of subsidies on basic items, and the deterioration in the social services upon which they depended (Witter and Anderson, 1991; Anderson and Witter, 1992; Freckleton, 2003; Alleyne and Karriagianis, 2003). No real economic growth has occurred in the country over the last three decades

Poverty line studies show the incidence in the island fluctuating annually. It reached its highest point in 1991 (45) percent (PIOJ/ STATIN 1993) and since then, has been fluctuating downwards. Rural rates are persistently higher than urban. In addition, one study explored levels of poverty in Kingston's inner city areas (www.idpm.man.ac./uk/crpc) and argued that despite a reduction at the macro level the situation remains the same in these areas. Annual remittances to the island have shown a remarkable increase (Figure 3.23) and although its effects on poverty has not been measured it was the most frequently source of income mentioned in Levy's study of inner city communities (Levy, 1996).



Source: Statistical Institute of Jamaica 2002

Fig. 3.23: Remittances (in US$ million) to Jamaica from 1990 -2001.

3.4.2.2 The Interviews

The presence of organization with an interest in sustainable development is seen as being indicative of high generic capacity since these are some of the institutions whose work can facilitate adaptation. A number of these organisations in the island was responsible for articulating the county's position on climate change and the Heads of these organisations were interviewed. The primary interest was in the scope of their activities and the extent to which they saw health as an outcome of sustainable development. The Office of Disaster Preparedness and Emergency Management has a mandate to manage all aspects of disaster management and risk reduction. It does so by an inclusive approach, working in partnership with other agencies. It is an approach which allows it to pursue programmes which would be impossible to carry out in isolation and also to influence national risk reduction. The informant from this organisation cited sea level rise and the inundation of coastal areas with resulting population displacement as areas that were of great importance. However, while the agency felt that they ought to be communicating their concern about climate change to the public, they had not included it in their public education campaign because

"climate change is not a simple topic to grasp. The average man cannot relate to it as it seemed very far fetched to him… its effects are long term and …individuals don't care about things that do not affect them immediately…"

They knew little about the possible health effects of the change but health was not seen as a part of their mandate. Besides, they said, there were resource constraints.

The National Environment and Planning Agency's (NEPA) mission is to promote sustainable development by ensuring protection of the environment. The issue of climate change was addressed indirectly in their public education programmes but ' the term was not used with the general public as it would be difficult to understand.' Instead, they concentrated on activities that would contribute to climate change in order to bring about behavioural change. The attitude of this agency mirrored that of ODPEM. Instead of looking for ways of communicating the message of climate change to the public they presumed a lack of intelligence and avoided the issue altogether. They, too, saw no need for the inclusion of the health threats in their mandate.

The National Meteorological Service saw its role as far as climate change was concerned in terms of conducting research for adaptation by those sectors that may be affected by the phenomenon and communicating the information to the stakeholders as well as the public. Unlike the officials at the other agencies, the expert here demonstrated a full appreciation of the health implications of climate change – those related to stress, respiratory diseases and the effects of increased transmission of vector-borne diseases. The public, he thought, should have access to information on the potential health consequences. With more resources, health impacts might be addressed by his organization although, he said, sea level rise would take precedence.

What was curious about these three interviews was the narrow interpretation of their mandates and the unwillingness to acknowledge health as a part of their remit even when it clearly was. Since its establishment in 1980, ODPEM has been called upon to deal with three types of hazards – hurricanes, landslides and floods occasioned by intense rainfall. Displacement of population resulting from hurricanes and floods have been accompanied by outbreaks of communicable diseases in shelters managed by ODPEM (Bailey, 1989) and this is one of the most critical areas in shelter management. Yet there was no acknowledgement of interest in diseases resulting from hazards. Moreover, much of the experience gained in hazard management occurred as a result of the occurrences of hurricanes and floods. These have been increasing in frequency and intensity and the island is being severely affected. Yet, the informant did not see the increased frequency of these events as some of the possible products of climate change and as more immediate threats than the effects of sea level rise.

In so far as NEPA was concerned, it was interesting that although the direct link between the health of the environment and that of the population was explicit in their mission statement and that the monitoring of effluent discharge and water quality had as their stated goal the protection of human health (www.nrca.org/publications) the position of the informant was that there was no interest in health. The literature produced for the public education campaign of the Meteorological Services contained information on health impacts. This was at variance with the insistence of the interviewee that there were no plans to incorporate health impacts into the education programme of the organization. In all the organizations there was this preoccupation, almost fascination with sea-level rise. Health was the business of the Ministry of Health and their reluctance to see themselves in partnership with the Ministry of Health and to interpret their remit and roles in the broadest sense limit the extent to which they could be regarded as providing a broad foundation for adaptation.

3.4.2.3 Specific capacity

The Ministry of Health

Key informants at the Ministry of Health comprised the Principal Budget Holder, two Medical Officers in the Surveillance Department, the Environmental Health Officer, a Public Health Inspector and the Health Educator. They were all aware that climate change in the Caribbean could produce increasing temperatures and precipitation most saw the possibility that these changes could increase dengue transmission. One of the officials, however, thought that increased transmission was a remote possibility and could see no reason for a dengue alarm in the island. In spite of the majority opinion, no long term strategies had been put in place or were being considered to cushion possible negative impacts. Dengue fever is classified as a Class 2 disease and was given significantly less priority than Class 1 diseases especially HIV/AIDS which is life threatening. There was repeated reference to the problem of inadequate funding and the resulting need to establish priorities. They cited cuts in budgetary allocations and an overall resource problem which have resulted in a reactive approach to dengue control and prevention.

There is a growing feeling, however, that the competition between HIV/AIDS and diseases such as dengue is not so much for financial resources as for attention. Large sums of money are flowing into the country from the Global Fund and this is having the unfortunate effect of diverting attention and manpower from other areas of the health sector. Alliance for Health Policy and Systems Research, an initiative of the Global Forum of Health Research and WHO, is encouraging research on the manner in which money disbursed by funding agencies such as the Global Fund to fight HIV/AIDS affects the broader health system. The research focuses on the policy environment, public/private mix, human resources, pharmaceuticals and commodities. This initiative is extremely important in view of the large amounts of new resources that are targeting specific diseases, as disease-focused programmes have a variety of direct and indirect effects on health care systems in general (Alliance for Health Systems Policy

Research/WHO, 2005). Moreover, the many bottlenecks in the under resourced health system are proving to be constraints on the effectiveness of programmes that target HIV/AIDS (Alliance for Health Systems Policy Research/WHO, 2005).

At the moment there is no vaccine which prevents dengue or DHF and the only effective method of prevention is the elimination of the vectors and their breeding places. The WHO has very clearly outlined priorities for control and a very important measure is epidemiological surveillance which includes both entomological surveillance and the monitoring of the types of human behaviours that contribute to larval habitats (WHO, 2002). In addition, according to WHO guidelines, health authorities are expected to improve emergency preparedness and response and strengthen national control programmes; to promote behavioural change through the development of guidelines for the sustainable prevention and control of vectors at all levels and to encourage/accelerate research programmes with an emphasis on pathogenesis, transmission dynamics and the building up of partnerships internationally and at all levels of the society (WHO, 2002).

These actions are represented as priorities by WHO, but for a variety of reasons the requirements are difficult to meet. Informants reported a staff shortage of as high as 50 percent at various levels in the Ministry including entomologists and public health inspectors. The situation is not expected to improve in the near future since, speaking of the position of public health inspectors one of the officials at the Ministry stated:

'…it will be difficult to find one; the salary is unattractive, the workload is heavy and they do not get the respect that they deserve.'

There is one under equipped virology laboratory in the island and this prevents the swift identification of dengue cases. Samples have to be sent to Trinidad and Tobago for identification.

Individuals have a role to play in vector control. They must ensure that their premises are free of the preferred habitats of Aedes and use source reduction techniques. They must also facilitate the application of residual insecticide and participate in community action to control larval habitats. Methods of achieving these ends must be communicated through public education programmes. Such programmes will facilitate individual action and also increase the effectiveness of public sector programmes of vector control. The importance of this type of input can be illustrated by the results of a recent study. Community spraying is sometimes undertaken in response to complaints of high levels of infestation. The habits of the vector require that all doors and windows be left open during this exercise but the study revealed that roughly 44 percent of respondents said that they close their doors and windows (Bailey, et al. 2005). Individual and community action is of paramount importance in control but the government must take the lead; they must establish partnerships with communities.

An informant in the Ministry of Health in the parish of St. James stated that as far as vector control was concerned, they operated on a zero budget. There was no routine exercise but knee jerk responses to reports of heavy infestation in specific communities or to special circumstances. She cited the preparation for the regional CARICOM Heads of Government meeting held in Montego Bay, St. James in 2003. The cost of the attempt at vector control in a small area around the hotels was J$ 289,400. On occasions such as these, geographical coverage is so restricted as to be little more than a palliative.

The position of the Ministry of Health was summed up by one of the informants. Environmental sanitation was the responsibility of members the community since they were the key players in the existence of mosquito breeding sites. Government intervention could result in a shift of responsibility from the community to the state. Gubler (2002) has in fact reported that government intervention and reassurance that they can control epidemics in Asia and the Americas have resulted in a false sense of security by the public who then do nothing to control breeding sites. A lot depends on the manner in which the message is transmitted. For effective control the message must be couched in terms of a partnership and, as the WHO insists, the surveillance and monitoring of behaviours to ensure that communities are adhering to their commitments are a part of the responsibility of the government. Community structures that would facilitate collective action are often lacking in situations where they are most needed. In addition, in Jamaica, the financial problems have also curtailed the public education programme that must underpin efforts to make communities more responsible.

One informant however, highlighted several positives aspects to the current situation. The country, she pointed out, has a well organised system of primary health care based on a nested system of health centres offering different levels of care. An exercise was undertaken in the late 1970s and early 1980's to ensure that there was a health centre within five miles of every community in the island (Figure 3.24) for this was the pillar on which the system of care rested. Moreover, health services have been decentralised and the island divided into four health regions (Figure 3.25) to enhance the delivery of care and to allow the participatory decision making that is important to adaptation.

It should be pointed out, however, that notwithstanding the overall reach of primary health care services, there are some rural areas that are disadvantaged both in geographic and socio-organizational terms. The services that are most needed are not always physically accessible.

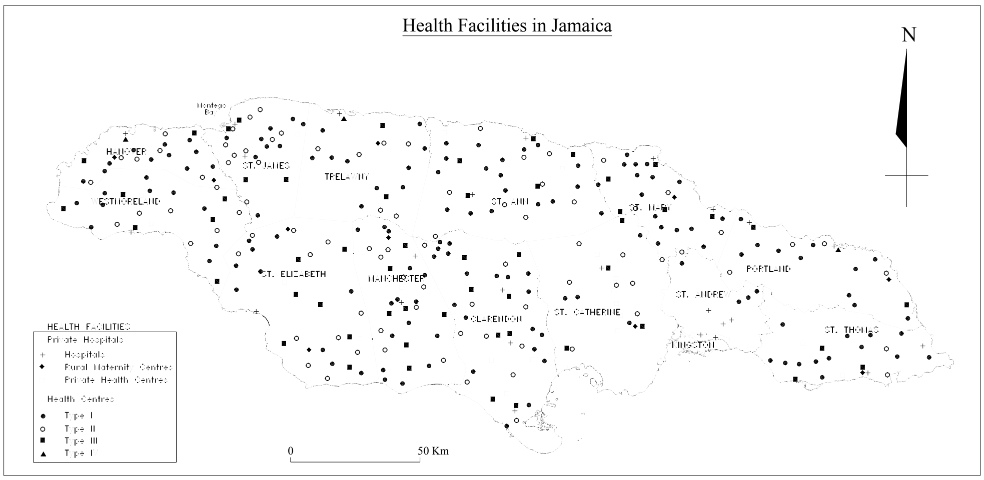


Fig. 3.24: Health facilities in Jamaica (obtained from Ministry of Health, 2004)

Another positive aspect is the recent decentralization of the health system. Up to 1995, the island's health sector was highly centralized with the Ministry of Health responsible for both policy making and day to day operations. With decentralization, four Regional Authorities were created with mandated to carry out health interventions in their respective regions. The Ministry now functions more in a regulatory capacity rather than in its traditional role as centralized manager. Regions now have autonomy in meeting their identified health needs. There is, therefore, greater sensitivity to local needs and there should be greater responsiveness in the event of outbreaks of epidemic diseases. Although the health system is affected by financial constraints there is a strong network, which could be mobilized in emergency situations

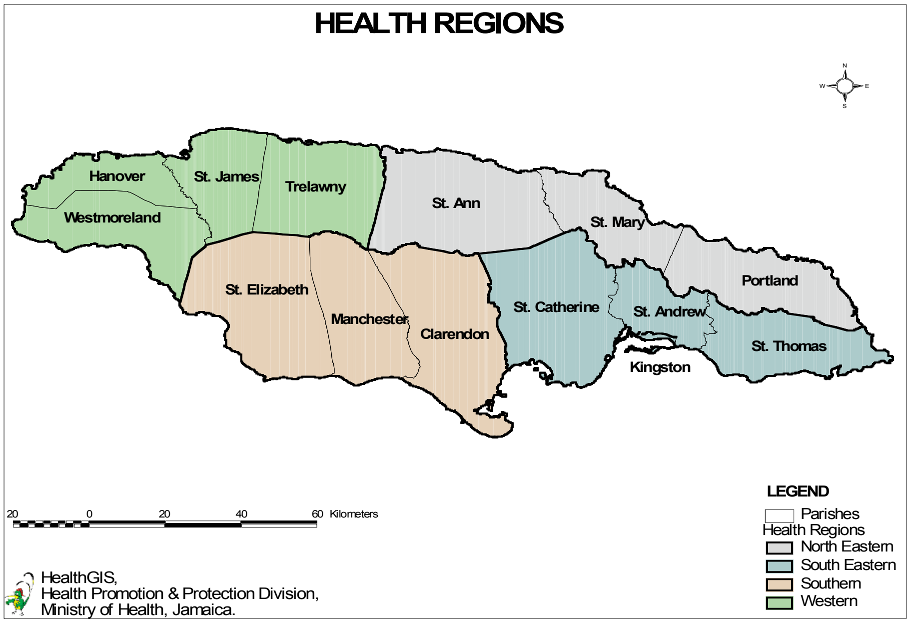


Fig. 3.25: Health regions (obtained from Ministry of Health, Jamaica)

Moreover, the interviewee continued, The Ministry of Health in the island has a long tradition of involvement in policy oriented research. This is unquestionably true. Few research projects in health with policy implications are undertaken in the University of the West Indies (UWI) without the involvement of the Ministry of Health. There are occasions in which the research/policy collaboration has been initiated by the Ministry with a view to investigating the effects of its policy on vulnerable groups (Gordon-Strachan *et al.* 2005). In fact, an official from the Ministry of Health is working closely with the Climate Change Group at the University of the West Indies on this dengue project. The work of this group is undoubtedly a positive element on the landscape and the collaboration of the Ministry would facilitate an easy flow of research evidence to policy makers.

The communities

Granville/Pitfour is a community of just over 6,300 persons on the outskirts of the tourist centre of Montego Bay. It is a low income community comprising a mix of formal and informal structures. Most of the informal structures consist of one-roomed dwellings and this community has the highest room densities (4.2) of the three under study. Heads of households were self-employed or worked in the service sector in Montego Bay. A few miles away is Retirement, a lower middle income community of 1,783 persons with few obvious informal dwellings. Heads were also employed in the service sector in Montego Bay and in the public service. John's Hall is a poor community of rural squatters. It consists of small crudely built houses, most lacking basic amenities and scattered over rugged terrain. Few heads were employed in agricultural pursuits even for their own subsistence and a part of the explanation for this may be the fact that roughly 60 percent of the households were headed by women. The women were of low educational attainment and lacked skills training. This placed at a disadvantage in the labour market and those who were employed were in domestic service and petty trading, activities that attracted incomes at the minimum wage or below. Male heads shared similar characteristics and were employed as gardeners and labourers on construction sites.

Unemployment in this community stood at 33 percent.

Wisner (1993) advocates a resource-based approach to measuring vulnerability, one that begins by asking questions about the situation in which people find themselves and the characteristics of groups. One needs to know about access to a variety of resources – physiological, social and economic. Using this approach, a matrix of social indicators is derived that can ultimately form part of a vulnerability profile that include gender, disability, access to resources and locational patterns. Responses given in the questionnaire survey were used to construct a vulnerability index based on a number of indicators identified in the literature. Although composite indices of this sort are useful in that they give a single value measure of vulnerability, it is recognised that the choice of variables is based on subjective judgements which affect results and that averages can conceal divergencies.

Effective public education campaigns are recognized as an important strategy to reduce vulnerability (WHO, 1997) and there were questions designed to assess the respondents' knowledge of the disease, its symptoms, and the use of protective measures. (Morens, et al., 1986; Dantes, et al., 1988; Ko et al.,1992). There are a number of socio-economic measures that are used to identify levels of resilience or stress. Among these are variables that are indicative of access to resources such as employment status, female household headship, and the need to employ coping strategies; access to critical infrastructure and services as well as an attitudinal dimension captured in a measure of willingness to accept responsibility for vector control

Gender has become recognized globally as extremely important in explaining poverty. Women face a bewildering array of social, economic and cultural discrimination that limit their access to economic resources and political participation. Data from Jamaica seem to indicate that the gender dimension of poverty is not as significant as in many other regions for there is an almost fifty-fifty split among men and women living in poverty (SLC, 2002). However, the situation changes drastically when one examines single parent households living in poverty, that is, the condition of many of the households in the study area. In 2002 (SLC), of the number of single parent households living in poverty, just over 66 percent were headed by females.

The level of vulnerability is a function of coping capacity and several questions were asked to assess coping mechanisms of households in the sample – the frequency with which households were forced to borrow money or take food on credit,; had to rely on relatives or friends and limited food intake. Responses were combined to form and index of coping and the general picture obtained was one in which large numbers were 'struggling to make ends meet.'

Households in which there is no piped water are more at risk than those with a piped supply because water storage becomes necessary. In the three communities, 23 percent had no water piped into their homes or yards and even when there was a piped supply respondents said that the supply of water was irregular necessitating storage of some sort. However, the degree of risk varies with the mode of storage. Chadee and Focks, (1997) working in Trinidad and Tobago, found that the outdoor drum was one of the most productive Aedes breeding containers and these were most commonly found in homes where there was no access to a piped supply. The authors found that four types of containers, the outdoor drum, tubs, buckets and small containers accounted for more than 90 percent of all aegypti pupae discovered. They concluded that the provision of an adequate water supply system and targeted source reduction had the potential to reduce more than 80 percent of pupal production in the country. In the survey in St. James, fifty-four percent of the respondents stored water in drums and, in the majority of cases, the drums were left uncovered both to facilitate the entry of rain water and for easy access to the stored water.

Many of the respondents did not know the vector of dengue and therefore the habits of the mosquitoes and this put them at risk. The Aedes species bites in the early mornings and at dusk and bednets that are so effective in the fight against malaria are ineffective in controlling dengue fever. The best forms of protection have been found to be screens or mesh on windows and doors (Ko et al., 1992). The mosquitoes must be kept out of the homes. Studies in Taiwan have shown that screens could eliminate as much as 63 percent of dengue infection and in Puerto Rico, the absence of screens showed a strong correlation with the occurrence of dengue fever (Dantes et al., 1988; Ko et al, 1992; Morens, et al., 1986). Repellents and mosquito destroyers are more accessible to low income households but they often force them into cupboards and other hiding places from which they later emerge. Screens were used on some of the houses in the formal settlement in Granville/Pitfour and Retirement. Eight percent of the sample used repellents but the majority used no form of protection at all.

Households consisting of disabled or ill members are considered more vulnerable since this translates into the number available for productive labour and puts a strain on household resources (Kouri et al. 1989; Nyong et al. 2003). The strongest association has been found with chronic illnesses which are often incapacitating and require strict adherence to therapeutic and dietary regimes. Overall, 50 percent of household heads in the survey suffered from chronic illnesses, mainly hypertension and diabetes. Rapid access to health facilities can minimize vulnerability and if access is measured in geographic terms, Granville/Pitfour was most fortunately positioned in relation to the comprehensive public sector services offered in Montego Bay, and John's Hall. least.

There is also the question of responsibility for vector control. Communities and the Ministry of Health have a responsibility for vector control and some communities accept this responsibility especially when it becomes apparent that the government is opting out of a situation which they have no resources to manage. However, when responsibility is diffuse and especially when there is a culture of dependence nurtured in low income communities by a political system based on patronage and largesse (Stone, 1983) members of communities may not appreciate the importance of their role in disease prevention. Seventy-eight percent of the respondents felt that dengue control should be the responsibility of the government.

Table 3.14 shows the scores obtained by the three communities and their ranking on each of the indicators. A score of 1 was given to the community that ranked lowest on each of the vulnerability indicators and 3 to the community that ranked highest.

Vulnerability indicators	**Johns Hall (%)**	**Score**	**Retirement (%)**	**Score**	**Granville/Pitfour (%)**	**Score**
No knowledge of dengue fever	52.6	2	53.1	3	42	1
No knowledge of disease symptoms	72	3	69	2	59	1
No protection	95	3	92	2	89	1
Income MW or less	68	3	33	1	61	2
Not coping	63	3	51	2	50	1
No pipe at home	46	3	12	2	11	1
Water storage in drums	65	3	53	2	44	1
Chronic illness	53	2	37	1	54	3
Distance from health facility	70	3	49	2	13	1
Female household headship	60	3	47	1	55	2
Public Health responsibility for dengue control	56	3	47	1	51	2
Total Score		31		19		16
1. least vulnerable	***2. vulnerable***	***3. highly vulnerable***	_	_	_	_

Source: Authors' fieldwork

Table 3.14: Composite of ranking for communities in St. James

Like poverty, vulnerability increased outward from the urban area. The score was lowest for Granville/Pitfour and highest for John's Hall. The difference between Granville/Pitfour and Retirement was small, an indication of the extent to which the informal community in Granville depressed its scores. Thus average scores do not tell the entire story. The question is what makes some groups more vulnerable than others? For this purpose of differentiating these groups a vulnerability index was constructed using scores of 0 and 1. A respondent who displayed vulnerability on a particular index, who, for example, had no knowledge of the vector, was assigned a score of 1. Where no vulnerability was displayed a score of 0 was assigned. A test of normality (mean ± 3 standard deviations) was applied to the results and this revealed that the data were normally distributed with a mean of 5.7 and standard distribution of 1.96. This made it possible to use the mean and standard deviation to create five groups displaying varying degrees of vulnerability (Table 3.15). The most vulnerable group (Group 5) comprised 24 respondents or 9 percent of the sample. The least vulnerable group accounted for 14 respondents or 5 percent of the sample. Most of those who fell in the most vulnerable group lived in the community of John's Hall. On the other hand, 64 percent of those classified as least vulnerable lived in Granville/Pitfour (Table 3.16). The conditions that characterise the vulnerable are the hallmarks of ignorance, poverty and exposure. Most households headed by women are at risk. The breadwinners eke an existence working as vendors, household helpers or seem to have no gainful occupation.

Group	Vulnerability	Total	Measure
5	Most vulnerable	24	Mean +1.5 SD >8.64
4		67	Mean + 0.5 SD to Mean + 1.5 SD 6.68 - 8.64
3	Average	51	Mean ± 0.5SD 5.72 – 6.68
2		101	Mean -0.5SD – to Mean -1.5SD 2.76 – 5.72
1	Least Vulnerable	14	< Mean – 1.5SD <2.76
			Normality Mean ± 3SD Mean = 5.7 SD = 1.96 Mean ± SD = 0.18 -11.58

Table 3.15: Identification of vulnerable groups

Characteristics	Group 5 (%)	Group 1 (%)
1. No knowledge of vector	92	7
2. No knowledge of dengue symptoms	96	14
3. No Protection	92	57
4. Minimum wage or less	92	21
5. Not Coping	83	0
6. Female headship	83	21
7. Storage in drums	79	21
8. Piped Water	50	0
9. Distance from health facility	79	7
10. Chronic disease	79	21
11. No personal acceptance for dengue control	83	7
Community with highest proportion	Johns Hall - **67%**	Granville/Pitfour -**64** %

Source: Authors' fieldwork

Table 3.16: Characteristics of the most and least vulnerable groups

The overwhelming majority had no knowledge of the disease, its symptoms and mode of transmission and this, together with their poverty mean that they are not in a position to protect themselves from the vectors of the disease. To most, protection against the vector is seen as protection against a mosquito nuisance. It is likely that if there is an association with the disease a greater effort would be made to take some responsibility for environmental sanitation.

Table 3.17 shows the characteristics of those falling in groups 4 and 2 and this table is interesting for what it illustrates about the community of Granville/Pitfour. Respondents in this community formed the majority in both groups. Granville/Pitfour has the majority of the least vulnerable but also groups that are vulnerable to dengue fever. Therefore vulnerability mirrors the dual nature of a community of formal and informal settlements and highlights the situation of squatter settlements in the island.

Characteristics	Group 4 (%)	Group 2 (%)
1. No knowledge of vector	75	21
2. No knowledge of dengue symptoms	83	48
3. No Protection	100	89
4.Minimum wage or less	69	38
5. Not Coping	75	37
6.Female headship	69	44
7.Storage in drums	54	44
8.Piped Water	31	10
9.Distance from health facility	48	16
10.Chronic disease	70	36
11.No personal acceptance for dengue control	63	39
Community with highest proportion	Granville/Pitfour-**48**%	Granville/Pitfour -**69** %

Source: Authors' fieldwork

Table 3.17: Characteristics of Groups 4 and 2

3.4.3 Conclusion

Results obtained from the work of the Climate Studies Group Mona at the University of the West Indies have established an association between climate variability and the occurrence of dengue fever outbreaks. Peaks in occurrences are associated with warmer conditions and the seasonality of the epidemics suggests that temperature and precipitation have some explanatory value. The prospective study is underway but preliminary results indicate a continuation of the warming trend. Caribbean islands therefore, should brace themselves for increasing outbreaks of a disease which is debilitating and which, in its DHF manifestations, can cause loss of life. The study has shown that a substantial number of people living in conditions which are conducive to the proliferation of the vector and virus are vulnerable. It has demonstrated the vulnerability of those living in informal settlements. The precise number of persons who now live in such settlements in Jamaica is not known but it has been estimated that the percentage for Montego Bay is 60, or between 55,000 and 60,000 persons (Ministry of Environment and Housing, 1997). It is clear that Jamaica faces a problem of great magnitude. Beset by with competing claims that are more urgent, the country does not see preparation for the possibility of a large outbreak of dengue as a priority and does not have the capacity to deal with such an occurrence.

Not unexpectedly, the poor were the most vulnerable. In 2002, 15 percent of the population of the island lived below the poverty line and since poverty was more prevalent in rural areas (PIOJ/STATIN 2002) these communities, which account for roughly 48 percent of the population, are more vulnerable. The poor are not necessarily unemployed. Many of the poor work – domestic workers, workers in the garment industry (Clarke, 2002; Henry-Lee, 2002). These are the groups that earn the minimum wage. Many poor households are also headed by women and this explains the vulnerability of female headed households in the study

There is merit to the view of the Ministry of Health that communities must take some responsibility for vector control. But this has to be a policy position rather than a defensive posture. As policy, it must be supported by initiatives aimed at empowering communities to assume control. Public education is necessary to address the knowledge gap revealed in the study. More than a half of those interviewed in the communities could not say what causes the disease and the overwhelming majority had no knowledge of its symptoms (Table 3.14). Vulnerable groups therefore, do not have the tools to protect themselves from outbreaks of dengue fever. In addition, responsibility is shared and the government's responsibility is clearly outlined the WHO. An important area that must be targeted in an education programme is the risk associated with improper water storage. Many rural areas do not have access to pipe borne water. Squatter communities in urban areas are not supposed, by law, to have a pipe borne supply. The problem of water has to be tackled on two fronts – the provision of low cost, secure drums and the granting of security of tenure to those who, because of their status, are denied access to running water.

There are public sector organizations that have been given the mandate to mitigate hazards in the island and to promote sustainable development. These organisations seem obsessed with the threats posed by sea level rise. No one can deny the threat posed by this phenomenon to small islands that have their most valuable assets and most of its people on low coastal plains. This is more attractive, more seductive than a health threat especially when the disease is known. But it is difficult to see why all public sector agencies should become so absorbed with the gradual encroaching of the sea to the exclusion of more imminent threats. They should be persuaded to broaden their concept of a hazard; that the threat of an increase in the occurrence of a debilitating and possibly deadly disease is not incompatible with their mandate; to see threats to health as threats to sustainable development and include these issues in their public education programmes. The Ministry of Health, by itself is in no position to meet the challenge of increased disease transmission in the island. There is need for a concerted effort of collaboration with various public and private sector environmental organizations. These are elements in the country's generic capacity, which constitute the foundation for adaptation.

4 Adaptation

4.1 Activities Conducted

Knowledge, Attitude and Practices (KAP) surveys were carried out in Trinidad and Tobago, St. Kitts and Nevis and Jamaica. These surveys were used to

elicit information on knowledge, attitude and practices from the population on the issues of climate change and variability and its impact on health in general, and specifically on dengue fever and Aedes aegypti. This information was needed to give an indication of the population readiness to modify vector production behaviour practices based on any forecast that was considered favourable for

In the final year of the project, Dr. Ian Burton was invited to a workshop in Jamaica to assist with the development of adaptation strategies. At this workshop, he discussed four key questions that should underpin adaptation investigations in the project. These were:

1. What was being done to contain dengue now at the present risk levels?
2. What explained the successes and failures of the current programmes, and how might present risks be further contained or reduced?
3. To what extent can the present level and design of public health programmes be expected to cope with the increased risks associated with the advent of climate change?
4. What were the possible ways in which programmes could be expanded and strengthened, and how can this best be undertaken given current budgetary and other constraints?

Dr. Burton also discussed several recommendations he had compiled for adaptation to dengue fever in the Caribbean. These were vector control strategies, increasing public information and awareness through health promotion and education, and the need for vaccine development. He suggested a methodology for cost/benefit analysis regarding adaptation strategies and emphasized the need for forecasting and warning which would serve to reduce dengue epidemics.

4.2 Knowledge Attitude and Practices (KAP) Studies in Trinidad and Tobago and St Kitts and Nevis.

4.2.1 Description of scientific methods and data

4.2.1.1 The study design

A knowledge attitude and practices (KAP) questionnaire document was designed to elicit information from sectors of the Caribbean people on issues of Climate Change (CC) and Climate Variability (CV). Questions were included in the Following topics:

1. Demographics
2. Understanding of the concepts of CC/CV
3. Links of CC/CV and the physical environment
4. Links of CC/CV and human health
5. Attitudes to disease prevention using CC criteria
6. Actual practices of disease prevention used by the community.

Two questionnaires were designed for each community. One asked general questions of issues 1 to 6, above. The second questionnaire dealt with observations of actual mosquito larval survey and vector prevention strategies such as environmental sanitation (ES) practices used by householders in the community. Questions were also asked and observations made such as the number of potential vector habitats on the property, those in use, those which in the opinion of the householder were disposable, and the frequency of inspection and ES efforts attempted.

A group of interviewers were trained in understanding the concepts of CC, CV and in administration of the questionnaire. Thereafter, a pilot survey was conducted by them to obtain information on any needs to further modify the document. Final changes were thus made in the questionnaire before it was ready to be made available to the public.

The first questionnaire was administered to the general community group verbally, but at the same time, allowing the subject to read the question for better understanding. At the end of the questionnaire discussion, a vector inspector requested the householder permission to examine the property for vector production and habitats. At this stage, the second questionnaire was completed. For the student group (from the same geographical areas), the questionnaire was self administered. However because the group was interviewed in the school environment, no vector survey was possible and the second questionnaire was omitted.

4.2.1.2 The population to be surveyed

Three Caribbean countries were selected for this KAP survey:

- Trinidad and Tobago, an example of a large population with high levels of DF endemicity.
- Jamaica, a large population with only intermittent DF transmission.
- St Kitts and Nevis (SKN), a small population with only occasional DF.

Only the T&T and SKN survey data are being presented in this report.

Community clusters were selected for 5 areas of T&T representing urban and rural components: there were two communities in northern Trinidad; Maraval and Arima; there were two communities in southern/central Trinidad; Rio Claro and San Fernando. There was one community selected in Tobago, in and around the city of Scarborough. For the student groups, a high school with a post-Caribbean EXamination Council (CXC) population within each selected cluster was chosen. Two hundred questionnaires administration attempts were made in each of the general community areas and one hundred to each of the student groups. This gave an overall questionnaire attempt rate of 1/1000 (1500/ 1.5Million population).

In St Kitts and Nevis, six community clusters around the island of St Kitts and one in Charlestown, Nevis were chosen for the study. Students were selected from the Fitzroy Bryant community college in St Kitts, which is the training facility for all post-CXC students in the state. In all, two hundred general community and one hundred student community interviews were attempted. This gave an overall questionnaire attempt rate of 11/133 (300/40,000 population).

4.2.1.3 Data management

Data from the surveys were entered and analysed by EPI Info (version 6) and SPSS. Means were obtained and any statistical differences demonstrated by X sq analysis.

4.2.2 Results

4.2.2.1 Response rates

There was a response rate of 43.3% (201 students and 449 in the general community) to the 1500 questionnaires (500 students and 1000 from the general community) administered in the 5 selected areas of T&T. In St Kitts and Nevis, there was a much higher response rate of 75.6% ; 51 of the 100 students and 176 of the 200 general community. Overall, there were 227 completed questionnaires in SKN and 650 in T&T.

4.2.2.2 Demographics

Of the 227 SKN respondents, 58.1 % were females, 37.9% males (4% unknown), while among the T&T respondents, there were 56.9% females, 40.6% males (1.5% unknowns). The SKN population was largely described as rural dwellers (63%), while 31% claimed to be urban. In T&T, our sample was 53% rural and 46% urban.

The largest single age component of our study groups for both countries was the 15 to 24 age group (34.5%) (Figure.4.1). There was a fairly even balance of other age groups in both countries. Overall, age presentations were 15 to 24 (34.5%); 35to 44(16%);65 and older (12.8%); 45 to 54 (12.7%); to 25 to 34 (12.2%); 55 to 64% (10.8%). Highest levels of educational attainment was secondary school education for both groups; 56.9%; SKN was 62.1% and T&T was 55.1%. The SKN group claimed a 22.5% tertiary education attainment while T&T was only 7.2% in this category.

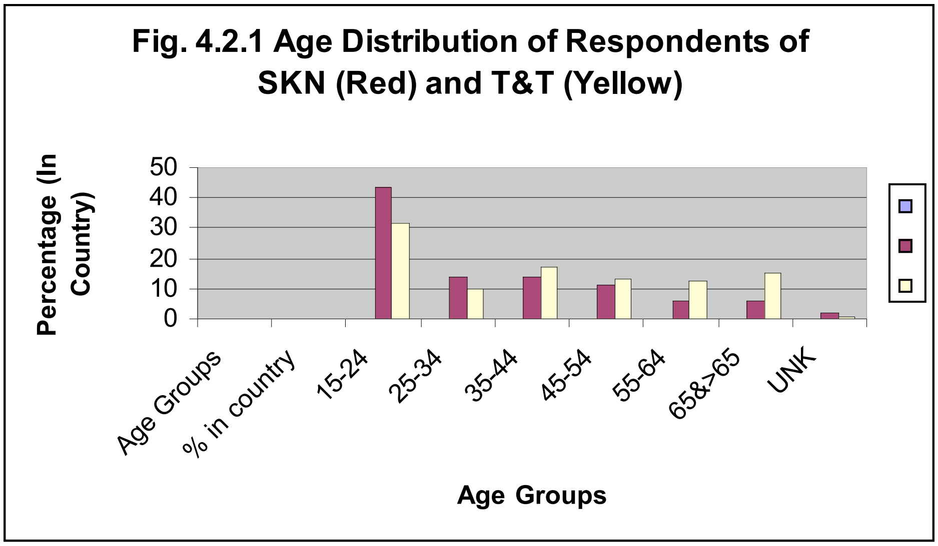


Fig. 4.1: Age distribution of respondents of SKN (red) and T & T (yellow)

4.2.2.3 Understanding the concept of "Climate Change"

Over 62% of the SKN population and 54.8% of the T&T respondents appropriately answered that CC referred to increases in temperature and rainfall in the last few years ($p< 0.001$), (Table 4.1). There were no significant differences between the answers from the two countries ($p=0.107$).

	Country			
	St Kitts/Nevis		Trinidad & Tobago	
Concept of Climate Change	n	%	n	%
Increase in Temperature (Last few years)	48	21.1	204	31.4
Increase in Temperature and Precipitation (Last few years)	142	62.6	356	54.8
None of the above	9	4.0	16	2.5
Don't know	16	7.0	46	7.1
No response	12	5.3	28	4.3

Table 4.1: Concept of climate change by country

With regard to the concept of "climate variability", both country respondents identified correctly that the term referred to seasonal changes in both temperature and rainfall (Table 4.2) Interestingly, urban persons from T&T, were more likely than rural persons to correctly attribute CC and CV to increased temperature and rainfall in the last few years ($p=0.09$) and to seasonal change in temperature and rainfall ($p= 0.0029$) respectively.

	Country			
	St Kitts/Nevis		Trinidad & Tobago	
Concept of Climate Variability	n	%	n	%
Seasonal changes in temperature	23	10.1	51	7.8
Seasonal changes in precipitation	9	4.0	33	5.1
Both of the above	177	78.0	497	75.6
Neither of the two	0	0.0	1	0.2
Other (unspecified)	0	0.0	2	0.4
Don't know	17	7.5	53	8.2
No response	1	0.4	13	2.0

$\chi^2 = 1.53$ df = 3 p = 0.67

Table 4.2: Concept of climate variability

In answer to questions on "causes of CC/CV", while small numbers of respondents referred to "greenhouse gases, holes in the ozone layer, burning of vegetation and vehicular exhaust fumes, the majority of respondents, 47.6% (SKN) and 50.2% (T&T), ($p> 0.05$), attributed CC to all these factors (Table 4.3). A sizeable proportion (39.2% (SKN) and 30.8% (T&T)), did not respond to this question.

	Country			
	St Kitts/Nevis		Trinidad & Tobago	
Causes of Climate Variability	n	%	n	%
Green house gases	5	2.2	7	1.1
Holes in the ozone layer	6	2.6	42	6.5
Burning vegetation	4	1.8	58	8.9
Vehicular exhaust fumes	5	2.2	26	4.0
All of the above	107	47.6	326	50.2
None of the above	5	2.2	12	1.8
Other Causes (Unspecified)	4	1.6	3	0.5
Don't know	1	0.4	8	1.2
No response	89	39.2	200	30.8

$\chi^2 = 16.58$ df = 4 p = 0.0023

Table 4.3: Causes of climate variability by country

In answer to questions in which areas of our lives CC/CV are likely to affect us, small proportions of respondents mentioned health, water resources, agriculture, biodiversity and coastal degradation singly, but in both countries, respondents selected all these issues combined – 54.6% (SKN) & 45.5% (T&T), as areas that CC/CV affect us most (Table 4.4).

	Country			
	St Kitts/Nevis		Trinidad & Tobago	
Areas	n	%	n	%
Health	13	8.6	70	14.1
Water resources	8	5.3	58	11.7
Agriculture	3	2.0	43	8.7
Biodiversity	3	2.0	8	1.6
Coastal degradation	1	0.07	3	1.2
All the above	83	54.6	226	45.5
None of the above	1	0.7	5	1.0
No response	43	23.8	141	28.2

$\chi^2 = 16.78$ df = 4 p = 0.0021

Table 4.4: Areas in which CC/CV affect us

When a ranking was given to these issues however, health > water> agriculture>biodiversity>coastal degradation were perceived as the number 1 ranking of human affairs affected by CC/CV, in both countries. Overall, while communities in both countries were overwhelmingly aware of the adverse impact as of CC on the communities (p< 0.001), the T&T populations were significantly more aware than their SKN counterparts (X=5.33; p=0.02)

When asked to specify the health issues that were affected by CC, most respondents did not answer the; 56.6% (SKN) and 54.3% (T&T), (Table 4.5). For SKN respondents, heat stress at 10.0% was the most important issue, while for T&T persons, food-borne disease > water-borne disease > heat stress were the major issues of importance. Vector-borne diseases only ranked 4th and 5th for SKN and T&T respondents respectively.

	Country			
	St Kitts/Nevis		Trinidad & Tobago	
Areas	n	%	n	%
Food-Borne Diseases	11	7.2	89	17.9
Water-Borne Diseases	10	6.6	82	16.5
Vector-Borne diseases	8	5.2	12	2.4
Respiratory Diseases	14	9.2	19	3.8
Heat Stresses	15	9.9	55	11.1
All the above	0	0.0	2	0.4
None of the above	16	10.5	11	2.2
No response	86	56.6	270	54.3
Don't know	0	0.0	1	0.2

$\chi^2 = 47.89$ df = 5 p = 0.0000

Table 4.5: Health issues affected by climate change and/or climate variability

Information sources on CC/CV and sharing

Individual sources of information (SKN) ranged from the family< print media<peers<electronic media, while for T&T, this ranged from the family<peers< print media<electronic media (Table 4.6). Respondents who selected all these 4 criteria represented the single majority of the SKN (41.3%), and the T&T 26.4% samples. These differed significantly p< 0.04 X= 4.18). Sharing CC/CV information was done to family, peers and the community, but 56 -57 of both country's respondents selected all three of these groups for information sharing.

	Country			
	St Kitts/Nevis		Trinidad & Tobago	
Source of Information	n	%	n	%
1. Peers	21	13.8	52	10.4
2 Family	1	0.7	24	4.8
3. Print Media	5	3.3	101	20.3
4. Electronic Media	24	15.8	176	34.2
5. All the above	63	41.4	131	26.4
6. None of the above	36	23.7	82	16.5

$\chi^2 = 55.64$ df = 5 p = 0.00000

Table 4.6: Source of information on climate change/variability

The potential link between CC/CV and dengue fever (DF)

There was a significantly greater proportion of respondents ($p<0.001$) who reported increased number of cases in the wet season as a link between CC and DF transmission (Table 4.7). The 54.8% of SKN and the 62.4% T&T respondents selected this option over increased number of cases year round or in the dry season. Respondents did however identify increased breeding habitats over increased temperature-related issues of speeding up the vector life cycle and virus replication in the mosquito host (Table 4.8). Indeed, all these features were selected by 43% of the SKN and 28% of the T&T respondents. These two differed significantly, $p<0.001$ ($X = 5.63$).

	Country			
	St Kitts/Nevis		Trinidad & Tobago	
Perceived Links	n	%	n	%
Increased cases year round				
Increased cases in wet season	91	54.8	271	62.4
Increased cases in dry season	0	0.0	4	0.9
All the above	48	28.7	106	24.4
None of the above	4	2.4	7	1.6
Don't know	13	7.8	12	2.8

$\chi^2 = 7.83$ df =4 $p = 0.098$

Table 4.7: Perceived links between climate change and dengue fever

	Country			
	St Kitts/Nevis		Trinidad & Tobago	
Perceived Effect	n	%	n	%
Increased breeding in containers	89	39.1	378	58.2
Warm Temps. Speeding up L Cycle	3	1.3	19	2.9
Increased virus replication	2	0.9	4	0.6
All the above	97	42.9	184	28.3
None of the above	16	7.0	26	4.0
Don't know	20	8.8	39	6.0

$\chi^2 = 29.4$ df =5 $p = 0.000019$

Table 4.8: Perceived effect of climate change/variability on virus

Best ways to reduce the DF transmission using CC/CV information

Source reduction of habitats for DF (vector) limitation was selected by both SKN (60.3%) and T&T (70.2%) ($p= 0.006$; X 7.38) (Table 4.9). Other methods such as pesticide usage or use of biological tools as well a leaving the efforts to the public health authorities were of lesser selection.

	Country			
	St Kitts/Nevis		Trinidad & Tobago	
Best Ways	n	%	n	%
Reducing the number of habitats	137	60.3	459	70.7
Pesticide usage at CC/CV	27	11.9	116	17.9
Use of biological control tools	16	7.1	29	4.5
Others	22	9.6	61	9.4
Don't know	31	13.7	57	8.8

χ^2 = 11.84   df = 4   p = 0.000019

Table 4.9: Best ways to reduce virus transmission using CC/CV Information

Using CC/CV information for DF prevention was seen as a positive move by 82% of both populations. However, of both country's respondents, 18 to 20% did not know whether they were prepared to educate themselves on the CC/DF links and had a willingness to work for ES all the time for vector mitigation. Indeed, 51 to 52% of these two country's respondents listed an inclination to be practically and positively involved with all these issues (Table 4.10).

	Country			
	St Kitts/Nevis		Trinidad & Tobago	
Strategies	n	%	n	%
Self educated about disease /CC link	17	7.4	51	7.9
Community knowledge about how to break transmission	23	8.0	58	9.0
Community involvement in Environmental Sanitation	3	1.3	11	1.7
Willingness of Community to work for Environmental Sanitation	11	4.8	65	10.0
All the above	119	52.4	454	51.5
Don't know	46	20.3	119	18.3
None of the above	15	6.6	29	4.5

χ^2 = 9.06   df = 5   p = .1065

Table 4.10: Suggested strategies for dengue prevention

On a general issue, 91% (SKN) and 93% (T&T) respondents favoured making a national health priority of using CC/CV information such as prediction and enhancing ES strategies at times of higher risk of transmission of DF if the link between DF and CC could be established and demonstrated (Table 4.11). However, on a practical issue, only 49.7% (SKN) and 45.1% (T&T) respondents claimed a current practical involvement in ES vs DF in the last two days, and only 17% & and 30% respectively were personally actively working in ES for DF prevention in the last week.

	Country			
	St Kitts/Nevis		Trinidad & Tobago	
Strategies	n	%	n	%
Two days ago	80	49.7	211	45.1
One week ago	27	16.8	140	29.9
One month ago	26	16.1	73	15.6
Last year	15	9.3	3	2.3

$\chi^2 = 39.72$ df = 3 p = 0.000

Table 4.11: Most recent involvement in environmental sanitation

4.2.3 Discussion

Up to the present, there has not been any significant discourse on CC and health issues in the Caribbean, though there have been discussions on CC and environmental issues such as coastal degradation. Worldwide, the impact of CC on health issues has taken a relatively lower profile than environmental issues (Kovats et al, 2001), and for each paper of evidence of CC impacting on a disease, e.g. malaria in the Kenyan highlands (Githeko and Ndegwa, 2001), there have been others challenging the veracity of this, e.g. Hay et al,(2002); Zell (2004). Obviously, there is a need for CC-based impacts on health issues to be carefully examined and evaluated, then presented to the community for their action in preventing disease.

Here in the Caribbean, we have already started to gather CC/health issues evidence. Rawlins et al (2004) and Amarkoon et al (2004) have recently presented some evidence of CC impacting on DF transmission in the Caribbean region. As far as respiratory diseases are concerned, evidence has come from Barbados and T&T on Sahara dust – thought to be related to global warming on the African continent – impacting on asthma in children (Blades et al 1998; Gyan et al, 2003). Thus, it is reasonable to ask how informed are the general Caribbean public about CC issues, and to enquire whether this information would be acceptable as a stimulus to enhance disease prevention strategies.

Our sample population of SKN and T&T did show a considerable knowledge of the nature and of causes of CC/CV (Table 4.3). However, the 31 to 39% who did not answer the question makes one wonder whether this was due to ignorance and therefore signaled the need for an educational campaign on the subject. Our expectation in this survey was to find a significant difference in the improved CC knowledge in high school students over the rest of the community, but there was no difference.

Data from our two Caribbean countries on the awareness of CC/CV, presented a mixed picture. The good news is that for both countries, the proportion who were aware of the CC impact was significantly greater than any other option ($p<0.001$). All mentioned that the impacts of CC affected water resources, health, agriculture, biodiversity and coastal degradation. Health and water were singled out as the most important issues affected by CC. (It is possible that the community recognized the questioners as public health employees and were thus influenced!). The alarming issue from our survey however was that when asked to specify the health issues, affected, 54 to 57% of the respondents did not respond; it was not possible to say whether this was due to ignorance. For our specific survey, CC impacts on vector-borne diseases was only ranked 4th and 5th by the SKN and the T&T respondents respectively. This may be considered to be evidence that the questioners (Vector control workers), did not influence our respondents.

4.2.3.1 CC information source and use

The electronic media – radio and television – as well as peers were the main source of choice, while the print media and family interaction were not so important to our respondents of both countries. For dissemination of CC information in a health promotion program, TV and radio will prove strategic because of widespread and easy usage especially by groups such as adolescents and young adults.

4.2.3.2 The perceived link between CC and DF

This is found to be is significant. The responses indicated that most respondents really referred to seasonal (wet season) changes rather than real CC. In both countries, little practical attention was paid to temperature change features such as speeding up o f the lifecycle of the vector or virus replication within the invertebrate host (Focks et al 1995). But there was reference to increased precipitation (and larval habitats) and correlation to increased DF cases really referred to our annual (seasonal) DF phenomenon (Rawlins et al 2004). It seems though that health education messages in the region in the last 10 years of promoting source reduction as a means of reduction of vector (Ae aegypti) abundance has had some success at least intellectually if not practically. Some 60 to 70% of our respondents were aware of this method, though these numbers should improve further.

Even better was the opinion of 82% of both set of respondents of the potential utility of CC/CV information for adaptation for DF prevention. However, only 51 – 52% of these two countries' respondents showed an inclination to be positively and practically involved in these DF prevention issues.

Even more, when 91 to 93% of our respondents opined on making a national priority of CC/CV information and seeing this as a useful tool for DF risk prediction and disease prevention, this proved to be theoretically excellent. However, there was less than 50% who are currently seriously involved (inspection and control within the last two days), for practical comparison. The drum/barrel Ae aegypti indices on inspection for SKN was 38.9% and for T&T, 12.3%. While this is not necessarily the best vector production indicator, it shows that a high proportion who currently opine that source reduction and environmental sanitation is the right way for DF prevention, are still producing Ae aegypti in their premises and their opinions on ES is only a mental issue which has not yet moved forward into essential practices.

4.2.4 Conclusion

To summarize, the present study shows that our two Caribbean countries' respondents demonstrated good knowledge and attitudes to CC/CV and to use of this information for adaptation for DF prevention. However, the issue of practical use of such knowledge has not yet been put into practice. This may be because no effort has been made as yet to assure the regions communities that CC is an important risk factor for enhanced DF transmission and that adaptation - taking special precautions at times of predicted high risk - could be a valuable additional tool to prevent disease transmission.

The future burden of the scientific community for use of CC/CV information and DDF mitigation remains to:-

- To demonstrate clearly to the public, the links between CC&DF. It is possible to make a case of risk predictability and apply this for vector and disease mitigation.
- Promotion of CC information, using alliances of health education for best community involvement and possible positive responses.
- Stimulate research on CC and other public health issues.
- Promote cross-disciplinary initiatives and studies for CC and the environment.

4.3 Knowledge, Attitude and Practice (KAP) Studies in Jamaica

4.3.1 Description of scientific methods and data

4.3.1.1 The study design

A questionnaire was used to solicit information from various communities across Jamaica on knowledge, attitudes and practices (KAP) relating to dengue fever. There were questions relating to the demographics of respondents, their understanding of the concept of climate change, knowledge of dengue fever and its transmission, attitudes towards disease prevention and actual disease prevention strategies used by the communities.

4.3.1.2 The sample

A representative sample of 300 respondents was selected from communities in urban and rural Jamaica using a stratified random sampling method. An attempt was made to select communities that were broadly representative of the Jamaican population. Clusters were selected from inner city and suburban middle/high income areas in the Kingston Metropolitan Area (KMA) and a community in rural St. Andrew as well as an urban and rural community in the parish of St. James. It was known from the fragmentary data on the occurrence of dengue fever in 1998 that some members of the rural community in St. James had suffered in that outbreak. Two hundred and forty two heads of households or just over 80 percent of the selected sample agreed to take part in the survey.

4.3.2 Results

Of the 242 respondents, 61 percent were females and 39 males. Sixty percent lived in urban areas and the rest in rural. Since 53 percent of the population of Jamaica has been classified as urban, this segment of the population was slightly over represented in the sample.

The largest single age cohort represented in the sample was the 24 to 34 group which formed 30 percent of the sample. This was followed by the 35 to 44 group. Altogether, respondents below the age of 65 formed 91 percent of the sample.

The highest level of educational attainment was secondary education accounting for 49 per cent. Those with a tertiary education comprised only 8 per cent of the sample. In so far as educational attainment was concerned, the Jamaican sample was similar to that of Trinidad and Tobago but below the level reached in St. Kitts/Nevis. Most respondents were employed and those who lived on their own were mainly renting.

Forty-eight respondents said that they had had dengue fever in the past and of these, 69 percent had contracted the illness on one occasion and 20 percent on two. Males were more likely than females to have the fever diagnosed by a medical practitioner.

4.3.1.3 Understanding the concept of climate change

Most respondents did not have a clear understanding of the term climate change. The largest single group (31 percent) felt that the term referred to short-term fluctuations in the earth's climate. Just under 24 percent regarded it as an increase in the Earth's temperature and almost as many as involving both temperature and rainfall increases. The percentage giving the correct response - - long term fluctuations in the Earth's climate was 22.

4.3.1.4 Causes of climate change

Just as many believed that climate change was the result of the pollution of air, water and land resulting from man's activities (34 per cent) as the work of God (34 percent). The rest felt that the process was the result of natural phenomenon and together, these three accounted for 98 percent of the responses. The supernatural element assumed greater importance in Jamaica than in the other islands. Only 3 persons claimed that they did not know the cause compared with more than 30 in Trinidad and Tobago and St. Kitts/Nevis.

4.3.1.5 Sources of information on climate change

Respondents received climate change information from various sources including their peers, family members, neighbours, electronic and print media. The dominant source of information was the electronic media mentioned by 23 percent of the respondents. This was followed by peers (18 percent) and the newspaper. As in the other islands, the family and neighbours were of least importance as sources of information on climate change.

Responding to the question as to which areas of their lives were likely to be affected by climate change, respondents gave a variety of responses. However, health was the most frequent response accounting for 29 percent of all responses. This was closely followed by agriculture (28 percent), water (27 percent) and biodiversity and coastal degradation (11 percent each). Others mentioned the possibility of natural disasters and soil erosion. In all the islands, therefore, health emerged as the area of greatest concern. Those who expressed concerns about health effects felt that climate change would result in an increase in the occurrence of diseases (89 percent) and facilitate a more rapid spread (3 percent) and increase mortality (3 percent). Only 4 percent of the respondents claimed that they did not know the mechanism through which climate change would exert its effects on health. In Trinidad and Tobago and St.Kitts/Nevis, the percentage that did not respond to this question was 54.3 and 56.6 respectively. The effect on water bodies would come about through pollution (57 percent) and drought (17 percent) primarily. It was also assumed that there would be a loss of crops and livestock creating food shortages; extinction of species and the destruction of the corals of the coast of the island. The percentage unable to specify the mechanism of change was highest for biodiversity (28) followed by coastal degradation (24).

4.3.1.6 Potential link between climate change and dengue fever

The majority (73 percent) of the respondents perceived an increase in the incidence of dengue in the wet season and only one (1) percent cited a link with the dry season. A substantial minority (25 percent) could not make any association. Those claiming for a link with the wet season argued that an increase in rainfall increased the number of breeding sites of the mosquito (62 percent) and also affected the development (17 percent) and life cycle (15 percent) of the vector. High temperatures were also believed to affect the development and life cycle of the mosquito. One of those who associated an increase in transmission with the dry season felt that was caused by an increase in water storage. More than a half of the respondents (57 percent) saw the possibility of an increase in transmission resulting from climate change given an expected increase in temperature and rainfall. However 31 percent of the respondents could see no relationship between climate change and the occurrence of dengue fever.

4.3.1.7 Knowledge of dengue transmission and disease symptoms

Eighty per cent of respondents knew that dengue fever was transmitted by a mosquito, however only 29 per cent knew the name of the mosquito - *Aedes aegypti* responsible for dengue transmission in the Caribbean. Respondents in urban areas were more likely than those in rural to know that mosquitoes were vectors although the difference was not statistically significant. The percentage claiming that they did not know was almost twice as large in rural as in urban areas. However, of those who knew that mosquitoes were vectors, significantly more ($p<.05$) rural respondents were able to name the mosquito and this was influenced by the high level of knowledge in rural St. James where more than 66 percent of those who cited the mosquito as the vector were able to name the species involved. It must be remembered that this was one of the areas involved in the last outbreak of dengue fever.

Respondents were also asked to name the symptoms of dengue fever. Not surprisingly, most respondents (77 percent) named fever, followed by pain (57 percent) and rash (30 percent). Respondents in the upper income area in the Kingston Metropolitan Area limited their responses to these three classical symptoms of the disease. Elsewhere conditions such as dizziness, weakness, upset stomach, vomiting, loss of appetite were listed. For the most part, these other conditions were named by the respondents in rural St. James. Relatively few (27 percent) were able to distinguish between the symptoms of dengue and dengue haemorraghic fever. In fact, very little was known about DHF.

4.3.1.8 Attitude

To the disease

Respondents were asked for their views on the seriousness of the disease and almost 91 percent felt that it was either serious or very serious. Just 7 percent felt that it was not a serious disease. In view of the seriousness of the disease, medical intervention was thought to be necessary (94 percent). They felt that such intervention was more likely to relieve the symptoms (92 percent) than cure the disease. A substantially lower percentage (59) considered DHF a serious or very serious disease and the percentage claiming that they did not know the answer to this question was 39 compared with less than 1 percent where dengue was concerned

To dengue prevention

Respondents gave a number of responses to the question as to their views on the best methods of preventing the breeding of mosquitoes. The employment of pesticides – oils, sprays – was the most popular choice (44 percent). Others felt that environmental sanitation (29 percent) and public education (27 percent) were most likely to yield results. Spraying was also seen as the best method of controlling the adult mosquito (62 percent) since it was effective in killing them (60 percent) and it was efficient in that in covered a wide area rapidly. But those who objected to spraying were concerned about its health effects and that the mosquitoes developing a tolerance to sprays. Those who harboured anxiety about the health effects of the use of pesticides had more confidence in public education ($p<.05$) and environmental sanitation ($p<.05$) than in the use of pesticides.

Responsibility for dengue control was seen primarily as that of the Ministry of Health (30 percent), followed by the individual, the community and the family. Eighty-one percent felt that enough was not being done by the MOH to control vectors – There was no public education (65 percent) campaign and almost 90 percent of those interviewed felt that there was an urgent need for this, there were no organized community clean-up exercises (66 percent); no regular spraying. In fact, almost 44 percent could not say when was the last time their community was sprayed. The majority expressed a willingness to be involved in public education campaigns centred on dengue fever

4.3.2 Practices

In all, 79 percent of the respondents said that they made an effort to control the breeding of mosquitoes around their homes through various forms of environmental sanitation methods and although those who believed that the individual had a responsibility to control the vector were more likely to give a positive response, the difference was not statistically significant. About 59 percent made an effort to protect themselves from being bitten by mosquitoes while indoors where they are more likely to be bitten by the vector and repellents were overall the most popular choice. Fewer (25 percent) protected themselves when out door and while repellents were also favoured for outdoor protection by urban respondents rural respondents mentioned smoke and the use of clothing.

Respondents were asked what preparations they make when they are warned that their community is to be sprayed. Forty-one percent said that they closed all windows and doors which defeats the purpose in view of the fact that *Aedes aegypti* is domiciliated. Thirty-four percent opened doors and windows and the rest made no preparations. In this regard, there was a significant difference in the practice of those who had objections to the use of spraying expressing a preference for public education as a form of control and those who believed in the use of pesticides. The former was more likely to close doors and windows than the latter.

4.3.3 Conclusion

The survey revealed that there is a deficit in knowledge of climate change at the community level. More than 50 per cent of the sample could not define the term or state the cause of climate change. A large sector of the population ascribe the phenomenon solely to supernatural causes and the implication of this is that they do not have an understanding of their role in contributing to and mitigating the effects of change. There is also a paucity of knowledge of dengue fever and many respondents had extreme difficulty in establishing a link between climate change and the transmission of the disease. It is quite possible that if more information on change within the Caribbean and its link with outbreaks of dengue fever were made available to the public, it might stimulate more interest and the concept may be less of an abstraction than it appears to be at the moment. To this end, the electronic media that seems to be an important source of information could be mobilized.

There is need for more public education on the transmission of dengue fever and especially DHF. The symptoms of dengue fever appear to be well known but there has been little experience of DHF in Jamaica and knowledge is correspondingly low. One of the effects of the circulation of several serotypes and the possibility of increased transmission consequent on climate change is an increase in the incidence of DHF. At the moment, it appears that there is no appreciation of the seriousness of the disease. As far as public health adaptive strategies are concerned, the WHO emphasized the benefits of public education programmes and the need for the population to be informed about the possible consequences of sequential infection and the nature of the threat posed by DHF (WHO, 2002). This level of awareness can only come about through a public education programme. Research has shown however that because of resources constraints, very little attention is being given to public education campaigns. Respondents in the study have shown that they recognize the benefits as well as the neglect.

4.3.3.1 Attitude toward vector control

The WHO (2000) believes that the primary responsibility for vector control is the government's. However, communities have an important role to play; the two must work in concert. The survey has shown that most respondents viewed vector control as a government responsibility. However, what was significant was that there was a tendency for those who saw that the individual had a role to play, to take an active part in vector control. This underscores the need for public education as a tool to empower communities to play an active part in vector control. One very positive aspect of the survey was the high level of willingness displayed by communities to work alongside the government in eliminating mosquito breeding habitats through community clean up exercises, for instance, 79% indicated that they would support such a venture.

There were many who were not convinced of the efficacy or advisability of spraying as a means of vector control. These were the respondents who placed the emphasis on environmental sanitation. Spraying is sometimes used, often in response to community complaints of high levels of infestation. Such exercises become more of a waste of resources if houses are closed to exclude the pesticide. It may be that such actions may be taken in ignorance of the habits of vectors. The need for public education and cooperation between communities and public health authorities to devise the best strategies for vector control and the reduction of transmission cannot be overstated.

4.4 Early Warning

4.4.1 Description of scientific methods and data

Understanding the relationship between climate and dengue fever gives us the ability to predict the potential for the occurrence of the disease since temperature, which can readily be measured and sometimes predicted, is one of the controlling factors of the disease. One of the components of this project was therefore to develop an early warning system for dengue fever. Several indices studied in this project and others reported in the literature were considered as indicators of dengue. These were the indices for the vector, viz., Breteau Index (BI), the Household Index (HI) and the container index (CI), the pupae/person index (PAHO 1994) and the Mean Average Temperature (MAT) index (defined in retrospective study, Chapter 2, Section 2 of the present report). The Pupal index was developed by Focks and Chadee (1997) to determine a threshold for number of pupae per person which would most likely lead to an event of disease epidemic. One reported threshold value for this index is 0.27 pupae per person (Focks et al. 2000). This index can be obtained as part of an epidemiology surveillance. However while the indices for the vector, BI, HI and CI, are fairly easy to obtain by counting containers and homes, the pupae per person index requires additional work of sorting pupae and is therefore a more difficult task. The MAT index is the easiest to obtain since temperatures are measured daily at meteorological stations and average values for months can easily be obtained from Meteorological Services. It was also demonstrated in the retrospective study that MAT is a better index for dengue than simple temperature measurement.

A review of the retrospective study shows in 1995 and 1998 the MAT in Jamaica crossed the average MAT value 0-4 weeks before the onset of the disease (Fig. 3.12). Similarly in Trinidad in 1999 and 2001 the onset of the disease occurred 4-6 weeks after the average MAT value was reached (Fig. 3.7), and in 1994 the lapse time was 8 weeks. Furthermore the slow approach to the average MAT value in 1992 is associated with late start of onset of the disease compared to other years. Fig. 3.8 shows that the early crossing of average MAT in 1998 was associated with an early onset of the disease, while the slow approach in 1997 was associated with a late onset. The crossing in 1996 and 2000 coincides with onset. It is therefore clear that the rate of increase of the MAT index and its approach to the average value can be used as a first indicator of the potential for disease epidemic. The MAT index is especially useful for timing an early or late epidemic. Once MAT indicates the potential for the disease, then other surveillance systems, can be put into place to determine other indices. Of the indices for the vector BI seem to be most closely associated with dengue occurrence. Fig. 4.2 shows a time series of the Breteau Index (BI) and Reported dengue cases in Trinidad from 1981 to 2001, which indicates a relationship between the two. Figure 4.3 which plots BI, reported cases and rainfall in Trinidad during the first year of the prospective study clearly shows that BI begins to rise before dengue reaches epidemic levels.

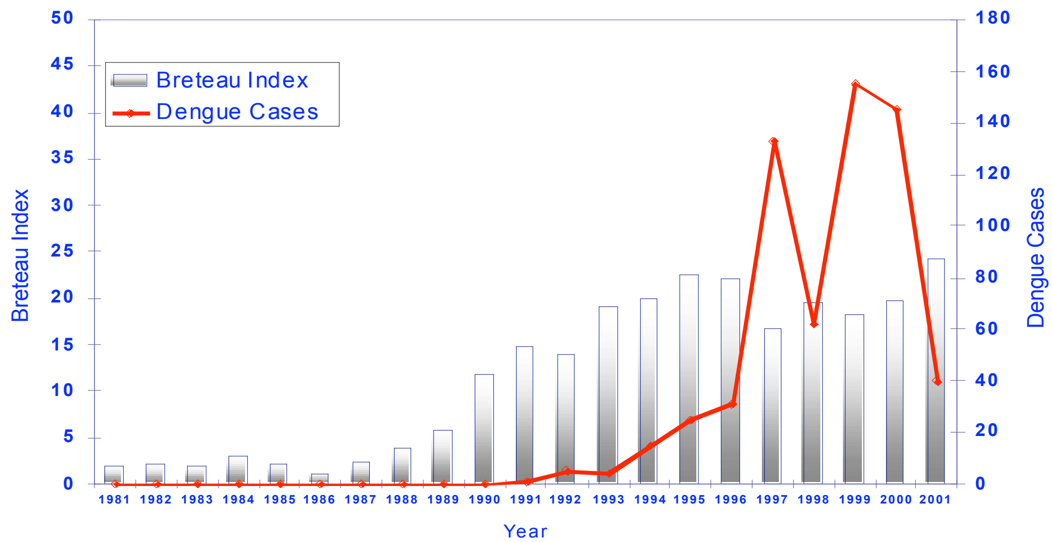


Fig. 4.2: Time series of Breteau Index and reported dengue cases from 1981 to 2001 in Trinidad

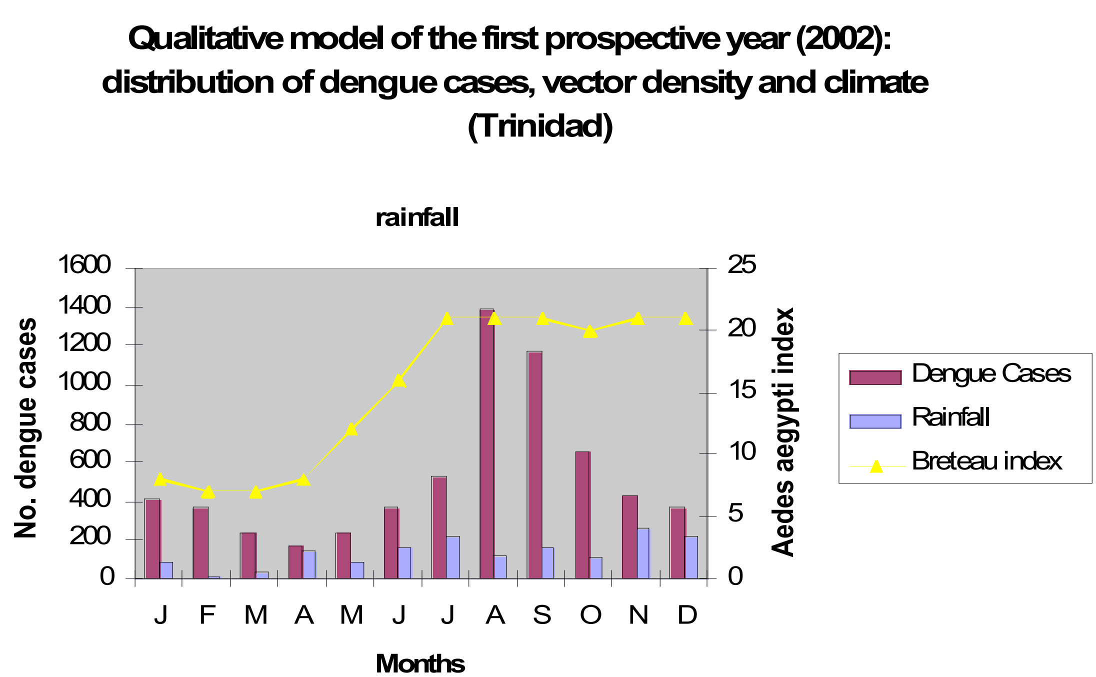


Fig. 4.3: Plot of Breteau Index, dengue cases and rainfall in Trinidad during 2002 Prospective Study.

The MAT index, the Breteau Index and the pupae per person index of themselves will only indicate the presence of conditions necessary for a disease epidemic. For the disease to spread the virus and a virus sensitive population must be present. To determine this presence, sero-prevelence surveys of the population can be carried out. However in designing an early warning system a major consideration has to be the cost of implementing the system. This was particularly important since dengue fever is classified as a class II disease, not one of high priority, especially when compared with HIV, so that cash strapped Ministries would not be inclined to fund early warning systems for dengue. A cheaper alternative to a campaign of sero-prevelence surveys is simply for Health Ministries to ensure that all diagnosed cases of dengue are reported.

4.4.2 Results

4.4.2.1 Warning

Keeping in mind the element of cost and the need to be as simple as possible so that Ministries will be inclined to utilize it, the early warning system which evolved was a check list of indices to monitor. In the order in which surveillances are to be carried out or indices monitored are:

i. Climate Surveillance for MAT Index
ii. Epidemiology Surveillance for Breteau Index
iii. Epidemiology Surveillance for Pupae per person Index (optional)
iv. First reported cases of dengue below the epidemic level

The MAT index is the easiest to monitor. It simply required data from an operational meteorological station. A more costly epidemiology surveillance need not be carried out until the MAT index starts to indicate favourable conditions for development of disease within the vector. When this occurs an epidemiology surveillance can be put into place, sending health inspectors into the field. The third step, epidemiology surveillance for pupae, can be omitted if it is too costly. I t will require some amount of training of the health inspector to sort pupae from larvae and to determine the amount of pupae per person. (The Supplemental Grant for AIACC SIS06 project provided funds for training of Ministry personnel, but the exercise is not yet completed.)

The responsible surveillance agencies for the MAT index could be:

- National Meteorological Offices, who would provide temperature data
- Climate Studies Group Mona, who would monitor the MAT index

The responsible agencies for the epidemiology indices would be the Ministries of Health of various countries in the region.

4.4.2.2 Response and Framework

The response would depend on the resources and policies of the individual countries. In section 4.5 below we present various response strategies. Ideally there should be a structure for climate and epidemiology surveillance and for ongoing evaluation and prevention (Fig. 4.4). There should also be a framework for risk analysis and vulnerability assessment, for issuing watch/warnings similar to storm and hurricane preparedness and for developing response strategies. The system must also be capable of communicating effectively with the public and of soliciting feedback. A schematic for such a system is shown in Fig. 4.5

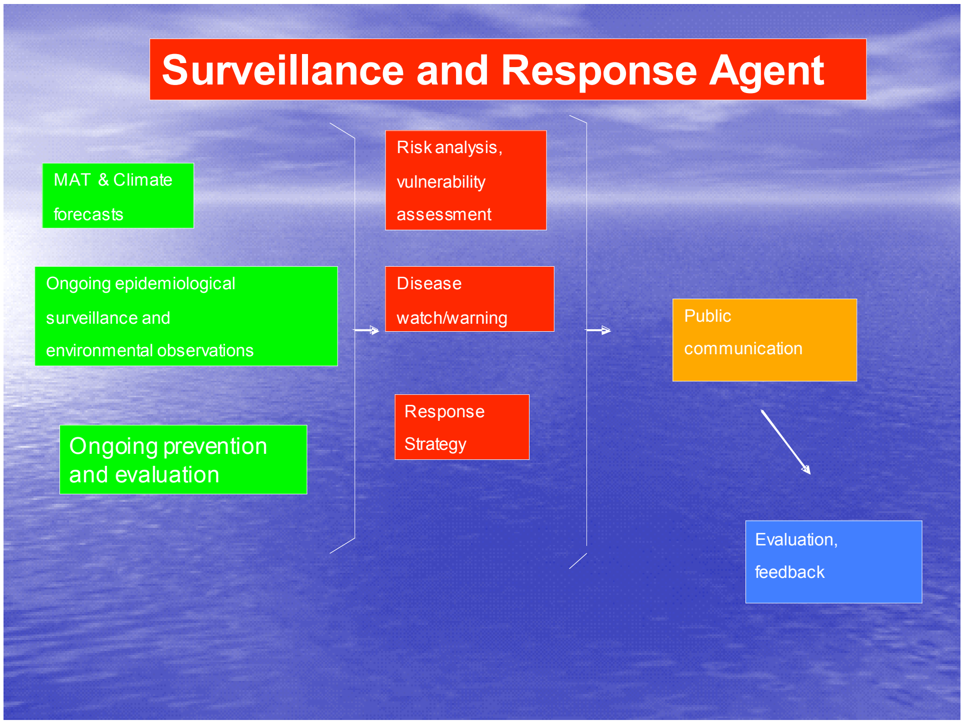


Fig. 4.4: Functions of a surveillance and response agent

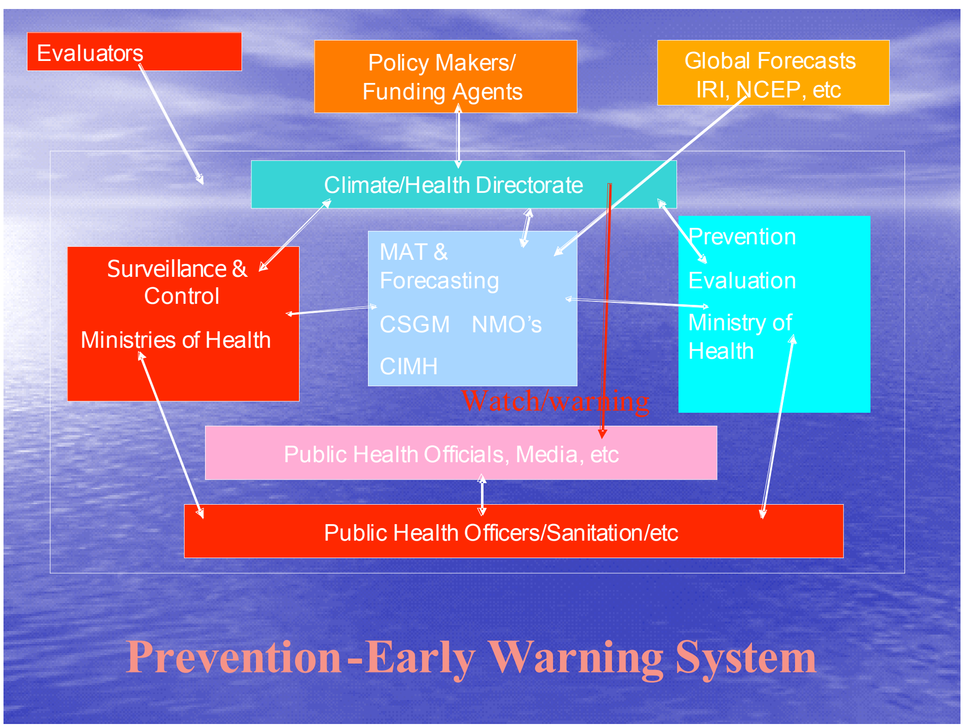


Fig. 4.5: Framework for an early warning system

4.4.3 Conclusions

The early warning system conceived above in its simplest form consists of monitoring a check list of factors which lead to the spread of the dengue disease. It is designed to be cost efficient and easily implemented. It is based on 2 findings of this project, the MAT index and close relationship between dengue and the Breteau index. Training in evaluating the third index, the pupae per person index, has been provided by a Supplemental grant to the SIS06 project. The project has therefore provided a potential early warning tool for stakeholder, which together with the adaptation or prevention measures described below should be of value to the stakeholders.

4.5 Adaptation Strategies for Present and Increased Future Risk of Dengue Fever in the Caribbean

4.5.1 Description of scientific method and data

The adaptation strategies for present and increased future risk of dengue fever in the Caribbean draw on the results of the retrospective and socioeconomic components of the project and answered specific questions, which include:

1. What are the current adaptive strategies that have been implemented to contain dengue at present risk levels?
2. What explains the successes and failures of current programmes and are adaptive strategies appropriately targeted e.g. targeting those factors directly affected by the climate stimuli?
3. To what extent can the present level and design of public health programmes be expected to cope with the increased risks associated with the advent of climate change? What are the adaptive constraints?
4. Can present programmes be expanded, strengthened or combined, or new programmes designed to better respond to the challenge of increased risk and in light of identified adaptive options.

4.5.2 Results

4.5.2.1 Adaptation strategies assessed

There is a marked similarity in the adopted strategies for handling dengue fever in the islands of the Caribbean. Because of the similarities it is possible to generalize about the strategies employed, highlighting where necessary the exceptions. We consider the measures of the Health Ministries of Trinidad and Tobago and Jamaica as both countries constitute the highest percentage of cases in our dataset and both have also expended resources in the recent past on the management of dengue fever. The strategies generally fall in one of three categories: Health Promotion and Education, Surveillance, and Vector or Adult Control. Practices covering all three headings are employed in both countries and are discussed below.

The Health Promotion and Education strategies generally target the entire population but only once risk is detected. Use is made of the media, posters, printed flyers and booklets and in limited instances health education teams in outbreak communities. Promotion conveys varying messages, including: the identification and elimination of breeding sites, symptoms of the disease, and disease treatment. Though both health ministries possess Education and Promotion units, neither has staff dedicated to dengue fever, nor do they make use of the media prior to the occurrence of an outbreak. Effectiveness of promotion strategies are measured by the reduction/increase in reported cases rather than an assessment of knowledge gained or changed behavioral practices. The assumption is that the former implies the latter.

As with Education and Promotion, the health ministries of both Jamaica and Trinidad possess Surveillance units staffed by government employed public health inspectors. In Jamaica, staffing is deemed inadequate and there is no routine surveillance of communities and dwellings except in response to outbreaks or to directives from senior health officials. Trinidad, on the other hand, employs in excess of

600 inspectors who conduct surveillance on a four monthly cycle. This is also deemed inadequate as the cycles do not necessarily synchronize with outbreaks nor do they help anticipate or reduce them. For both countries, the emphasis is placed on identifying breeding sites, recording epidemiological measures of vector abundance and source reduction of larval or pupal abundance, particularly in regions with recorded or suspected cases.

Finally, control of adult mosquitoes is carried out on request or directive and involves the use of ultra low volume (ULV) or thermal fog sprays. Though the consensus of the health ministries is that its effectiveness is short term (a few days), it is an oft demanded solution to intolerable adult mosquito levels. Fogging is an expensive exercise and is therefore limited to areas where outbreaks have occurred or where risk is high due to the abundance of adult mosquitoes. Other adult control practices are usually initiated by individuals within communities largely to alleviate the nuisance of mosquito bites. These include reducing vector-human contact through the use of repellants or the installation of mesh screens on buildings. There is no sustained program aimed at the reduction of larval or pupal abundance. On request there is limited chemical control through the use of Abate granules.

As is obvious, a primary weakness of current adaptation strategies is that they are reactive rather than anticipatory. In general, reactive strategies are palliative, do not serve to engender long term behavioral change, and help to institutionalize the idea of the government as ultimately responsible as opposed to community or personal responsibility. Even the best education programs never become engrained as the actions they purport as necessary to reduce risk are viewed by those they target as seasonal activities to be carried out if mosquito levels become intolerable. The general lack of sustained anticipatory action means that the populations of the Caribbean have developed a high tolerance for mosquitoes and mosquito bites and the risk reducing strategies themselves therefore lose some of their inherent effectiveness because they are often deployed (called for) late in the vector and/or viral development cycle.

Cuts in budgetary allocations to the health ministries and an overall resource problem are the primary reasons for the reactive approach to dengue control and prevention. In Jamaica, dengue fever is classified as a Class 2 disease and is given significantly less priority than Class 1 diseases, especially HIV/AIDS which is life threatening. There is correspondingly a lack of adequate manpower and facilities to tackle the problem on an ongoing basis e.g. there is only one understaffed virology lab in Jamaica and samples have to be sent to Trinidad and Tobago resulting in delays in identification of an outbreak.

Yet, although the health system in Jamaica is affected by financial constraints, it does possess a strong network, which can be mobilized in emergency situations. Primary health care is well organized and based on a nested system of health centres offering different levels of care. As a result of an exercise undertaken in the late 1970s and early 1980's, there is a health centre within five miles of every community in the island. A decentralization of health services has also resulted in the division of the island into four health regions. This enhances the delivery of primary care by allowing autonomy in meeting the identified health needs of a region. There is, therefore, greater sensitivity to local needs and the potential for greater responsiveness in the event of outbreaks of epidemic diseases.

The current adaptive strategies however do nothing to address the issues of the most vulnerable i.e. they are not very effective at making the vulnerable less vulnerable. Limited financial resources constrain the ability of the adopted strategies to respond to water access and storage issues. They do nothing either to rally or facilitate collective action, nor do they assist in transferring responsibility from governments to communities.

4.5.2.2 Adaptation options assessed

In Table 4.12 we offer a matrix of possible adaptation options available for coping with an increased threat of dengue fever. The methods listed include those currently employed in the Caribbean region (as discussed in the previous section), other options practiced elsewhere in the world or on a very limited scale within the region, and options that present themselves as future (though not too distant) possibilities, as a result of ongoing research in the region.

The options are assessed on six characteristics which are rated High, Medium and Low. For example, Cost is a serious adaptive constraint and so each proposed adaptation option is rated on the likely cost of implementation within the context of the Caribbean region. The assessments are made on the basis of a best guess and expert opinion. The assessment characteristics are: (i) cost to implement (ii) effectiveness (as measured by its long term ability to reduce risk or address vulnerability) (iii) social acceptability (iv) environmental friendliness (v) promotion of neighborliness, and (vi) technical and/or socioeconomic challenges to implementation. A simple composite score is offered in the final column for comparison purposes. In compiling the score, High is given a score of 5, medium a score of 3 and Low a score of 1, except for categories (i) and (vi) where the scoring allocation is reversed. The maximum possible score is 30. The strategies again fall under the three main headings of Health Education and Promotion, Surveillance, and Adult and Vector Control. They are also divided into short term and long term practices i.e. whether their intent is to immediately alleviate the threat associated with dengue fever or to do so gradually.

MEASURES	Cost	Effectiveness	Social acceptability	Friendly for environment	Neighbour effects	Technical challenges and socio-economic change	Score
Short term							
1. Adulticide (ULV or thermal fog sprays) in truck or air	H	L	L	L	L	H	6
2. Education (disease symptoms, sanitizing the environment).	M	M	H	H	H	M	24
3. Surveillance for vector or larval/pupal control.	H	M	M	M	M	L	18
Long Term							
1. Surveillance for vector or larval/pupal control and environmental sanitation	H	M	M	M	L	L	16
2. Community education and involvement.	M	H	H	H	H	M	26
3. Chemical control	H	M	M	L	M	L	16
4. Biological control	H	H	M	H	M	M	20
5. Adult Control							
- Physical-mesh windows	M	H	H	H	H	H	24
- Personal protection	M	M	M	M	M	H	16
6. Use of physical control- low cost secure drums	H	H	M	H	H	H	20
7. Granting security of tenure to squatters	H	H	H	M	H	H	20
8. Early warning system	M	H	H	H	H	H	24

Table 4.12: Adaptation Strategies Matrix. Columns 2 through 7 indicate assessment criteria. Column 8 gives a composite score based on the ranking in columns 2-7. Assessments are on the basis of High, Medium, and Low. In compiling the composite score, High is given a score of 5, medium a score of 3 and Low a score of 1, except for columns 2 and 7 where the scoring allocation is reversed. The maximum possible score is 30.

The short term strategies are those discussed previously and currently adopted in the region, namely: public education aimed at encouraging individuals to identify and eliminate current breeding sites and to identify dengue symptoms, surveillance in outbreak communities for the purpose of environmental sanitization, and adult control through the use of fogging. Of the three, public education achieved the highest composite score while adulticide via fogging achieved the lowest score. Education benefits from the fact that in the present framework it is generally medium to high raked in each category.

Its effectiveness is medium ranked due to the seasonal nature of the campaign, while the presence of established units to handle education accounts for the medium (as opposed to high) ranking with respect to cost and technical challenges. Fogging, though oft demanded and practiced, suffers from limited long term effectiveness, an inability to promote neighborliness (people shut their windows), limited social acceptability (the fog has a distinctly chemical smell) and the need for specialized equipment.

A number of possible long term strategies are presented in Table 4.12. Education strategies again achieve highest composite ranking (though marginally) with the focus here being on a sustained campaign aimed at community education (as opposed to targeting individual behavioral practices) and community involvement. Chemical control,

surveillance practices, and strategies relying on the individual to personally protect themselves received lowest scores. Surveillance as a long term approach does not engender neighborliness (general suspicion), while the best personal protective measures come at a cost to the individuals thereby limiting their possible use by the poorest who are the most vulnerable.

Generally however most strategies fall in the mid range of scores (16-24), suggesting that relative advantages in one area is offset by disadvantages in other areas. Physical control via the use of low cost covered drums would address vulnerability issues surrounding water storage but such drums or drum covers are yet to be designed and would have to be subsidized or made available free to the most vulnerable. Granting security of tenure to squatter individuals would promote community structure and increase the possibility of the eventual implementation of appropriate infrastructure for regular water supply. Such a move however is costly and fraught with social tensions. Biological control e.g. using fish to control mosquito population is an environmentally friendly option but is not suited for community practice. Finally, using an early warning system for action would imply the coordination of a number of agencies (e.g. climate research and monitoring agencies and health ministries) and the development of appropriate thresholds for action and coordinated action plans.

4.5.2.3 Best practices recommendations

No single "best" adaptation option exists to counteract the threat of increasing dengue fever within the Caribbean. As suggested by Table 4.12, the variety of strategies have their relative merits and demerits. In light of that, three options are offered as possible ways of approaching/tackling the adaptation problem. Each option represents a combination of selected strategies outlined in Table 4.12 with due consideration given to their relative strengths and weaknesses. The options also give primacy to the need to address the issues of vulnerability, namely the lack of knowledge about dengue fever, the lack of community structure to facility collective action, and the issues of water storage. The options increase in human and economic investment required and all assume that the currently practiced strategies outlined are at least maintained.

Option 1 – Refocusing current strategies

Option 1 advocates that currently employed strategies at least be maintained at their present level of activity and funding, but that approaches to them be refocused, and relatively minor modifications be made. Education is emphasized as the linchpin of this option with however a slant toward the personal and community good that would derive from the environmental sanitation and vector control strategies proposed in the campaign. This is as opposed to merely providing information about the disease and the steps to be taken to reduce mosquito abundance. A proposed modification would also be to engage communities prior to the rainy season through organized activities in nearby churches, schools, youth and service clubs and utilizing competitions to test knowledge and community cleanliness. Involvement prior to dengue onset would promote long term behavioral change (not just a dengue season problem) and community responsibility.

Vector surveillance in its current form would provide support for the educational activities, particularly approaching the dengue season. Option 1 would call for the least additional investment, though an upgrading of the capacity of the education and promotion units of the health ministries to initiate and sustain activities outside the dengue season would be required. The possibility of cost sharing with the engaged community groups should also be explored.

Option 2 – Plus proper water storage

Option 1 does not address the vulnerability issues surrounding proper water storage. The proposed adaptation strategies in Table 4.12 (design of drums and covers and security of tenure) are however costly, and consequently option 2 requires even greater investment by the ministries of health.

For option 2, the refocusing actions of option 1 are still undertaken as they address education deficiencies and community involvement and responsibility. These were two previously identified characteristics of the most vulnerable. In addition however, the design of a suitable low cost water storage drum or drum cover would be actively pursued. Currently, water is stored in discarded 'oil' drums which are left open to catch water running from rooftops when it rains. The open nature allows for the breeding of the vector. A covered low cost unit which allows water in and whose cover is easily removable but secure, or from which water can be easily removed otherwise is the ideal. The option to design a drum cover that meets the latter characteristics also exists as the currently commonly utilized storage drums are fairly standard in size. Such units/covers do not exist currently and might be costly to design and manufacture with little guarantee of their eventual use by the community. To ensure the latter, incentives would have to be offered e.g. subsidies and an intensive public education undertaken emphasizing the value of the drums/drum covers.

Option 3 – Plus an early warning system

Like option1, an early warning system has the advantage of anticipatory action. However whereas option 1 promotes education simply based on the knowledge that there is a dengue season, an early warning system attempts to gauge the severity of any possible outbreak. Consequently enhanced or diminished responses can be made on the basis of the anticipated level of threat. Option 3 therefore proposes the actions of option 1 but coupled with an early warning system. An example of the structure of a simple early warning system is given in Figure 4.5. Monitoring of climatic indices would be undertaken by the meteorological services, the regional universities and/or the regional climate research institutes. On this basis, the frequency of surveillance would be altered and the education campaign tailored to meet the level of perceived threat. Other strategies such as chemical or biological control would then also be employed given the advanced notice of threat. The implementation of option 3 however requires a memorandum of understanding between the cooperating institutions, a definition of roles, a focal point, some investment in research, and the possibility of staging of a pilot project.

4.5.3 Conclusions

From 1991 onward, there has been a significant increase in dengue cases in the Caribbean, and currently there is concurrent circulation of all 4 dengue fever serotypes. The increase can be linked to climate as both the abundance of vectors and the transmission rate are modulated by temperature and rainfall. There is a marked seasonality in dengue outbreaks, and extreme changes in the climate stimuli (e.g. as occur during an El Niño or El Niño+1 year) also seem to increase the risk of severe outbreaks. Current adaptation strategies within the region are limited as they are reactive rather than anticipatory and concentrate largely on reducing vector abundance and to a lesser extent on reducing contact between the vector and humans. They are necessarily so as a result of cost which is the major adaptive constraint. Though the two strategy foci are important, the current strategies do nothing to make the most vulnerable less vulnerable to the disease. The most vulnerable to dengue outbreaks are the poor for whom water storage is critical and who lack adequate knowledge of the disease and a sense of neighborhood that can promote community action. Adaptive strategies that target these issues, particularly water storage, are ideal though not necessarily easy or practical to implement within the Caribbean context.

Three options are offered which combine existing strategies and for which implementation capacity will vary based on levels of resources and commitment to adaptation. These are: a refocusing of current strategies with an emphasis on sustained education and community involvement; the abovementioned refocused education based initiatives along with a technological solution to water storage issues; and the refocused education initiatives and the implementation of an early warning system.

No option is offered as a best solution, but we suggest that at the least option 1 should be seriously considered. We reiterate again its aims and advantages, namely the transfer of information, the transformation of behavioral practices, the engendering of community spirit and action and the gradual shift of responsibility for alleviating the dengue threat to government-community partnerships. We finally note again that even at current levels of threat, there is an inability to cope, and reported cases are continuing to increase. Inaction is therefore not an option for the Caribbean in light of increased future threat due to anticipated climate change.

5 Capacity Building Outcomes and Remaining Needs

Five staff member of The University of the West Indies, Mona, Jamaica and St. Augustine, two from the PAHO/WHO Caribbean Epidemiology Centre, Trinidad, and several from the Ministries of Health, Jamaica and Trinidad and Tobago were involved in the project. One of the achievements of this project is that the researchers at these institutions have learnt the interdisciplinary techniques of studying climate change impacts on dengue occurrence and adaptation strategies using both climate and epidemiology data. There is also ample evidence that, now that the project has been completed, collaborative research on climate change between the two institutions will continue, by self financing means and otherwise, since the institutions are dedicated to research. Collaboration will be especially important when new climate change scenarios become available and new disease trends emerge.

In addition, a major component of the project was the training of graduate students. Five of these students were enrolled at the University of the West Indies' Physics and Geography Departments, Mona Campus. These are Lawrence Brown, Rainaldo Crossbourne, Cassandra Rhoden and Roxanne Stennett who pursued Masters of Philosophy (M.Phil.) in Physics and Charmaine Heslop-Thomas in the Department of Geography. Mr. Crossbourne and Mrs. Heslop-Thomas have submitted their theses on database development and socioeconomic studies respectively and are expected to graduate in November 2005. Ms. Rhoden and Stennett are writing up their theses in the area of scenario generation and retrospective analysis respectively. The project also supported the work of Ms. Karen Polson who is registered for a Ph. D degree in epidemiology at the University of the West Indies in St. Augustine, Trinidad.

As a result of working on the project, these students were given the opportunity to participate in numerous local and international workshop and conferences on climate variability and change. Progress was made in building capacity in downscaling when a student, Lawrence Brown, was sent to the intensive course on dynamical and statistical downscaling in Canada with assistance from funding under an Adaptation to Climate Change in the Caribbean (ACCC) Project (IDRC funded) This development continued throughout the AIACC project, and as a follow up, a Canadian expert, Dr. Gary Lines, was brought to the Mona campus of the University of the West Indies to consolidate the training. An expert from Europe, Dr. Aristita Busuioc (Fig. 5.1), traveled to Jamaica for an advanced course in downscaling for graduate students. A student, Roxanne Stennett, was also sent to the Summer Colloquim on Climate and Health, **N**ational Center for Atmospheric Research (NCAR)**.** Karen Polson, a student working at CAREC, visited the University of Texas Medical Branch for training in laboratory techniques to study the effects of temperature on the disease vector. In addition a student, Rainldo Crossbourne, was sent to The University of Puerto Rico, Mayaguez, for training in database development.

Staff benefited by making contacts and learning of new approaches used by others, and students benefited by gaining exposure and experience by making presentations, all from attending workshops and conferences. These were:

i. Workshop on Vulnerability Analysis, Trieste
ii. AIACC regional workshops in Costa Rico and Buenos Aires
iii. Conference on Climate and Health in Wengen, Switzerland
iv. Workshop for stakeholders in Jamaica and Trinidad
v. Workshop on Vulnerability, Belagio
vi. Workshop on Adaptation, Kenya

The students have been encouraged to continue their career paths in fields where their acquired skills can be used directly or indirectly in governmental, environmental, educational and/or research institutions. For example, with seasonal to interannual predictions of climate and applications of such predictions becoming more recognized and used in planning, meteorological services in the region will be looking for persons with skills in database building and statistical downscaling. Some students who worked in this project will be able to fulfill this demand however finding such employment for the students remains the most pressing need.

Capacity was also built in database development and accessibility. The development of the climate database was described in Chapter 3. A computer and accessories were also acquired to house the database and make it accessible to researchers over the internet.

Fig. 5.1: Dr. Busuioc instructing postgraduate students in theory and methodology of statistical downscaling.

6 National Communications, Science-Policy Linkages and Stakeholder Engagement

6.1 Workshop for Stakeholder Engagement

Towards the end of the project workshops were held in Jamaica and Trinidad and Tobago with stakeholders to outline the results of the project and their potential for decision making. The results were well received at both workshops, and the Director of Disease Prevention and control Division of the Ministry of Health in Jamaica has indicated that she would like to set up a simple form of the proposed early warning system, and meetings are to be arranged to discuss this matter. The workshops were held at the campuses of the University of the West Indies in Trinidad and Tobago and Jamaica on April 25 and 29, 2005 respectively. There were about twenty-two (22) persons in attendance at the Trinidad and Tobago workshop (Fig. 6.1.1) including:

- The Campus Principal, Dr B. Tiwarie
- The Dean of Sciences (Dr D. Narinesingh)and Head of the Dept. of Life Sciences (Dr G Sirju-Charran)
- The Director of the Caribbean Epidemiology Centre (Dr James Hospedales)
- Representative of the Minister of the Minister of Public Utilities and the Environment Ms P. Beckles– Dr David Persaud
- Dr Balkaran Shivnauath, Principal Medical Officer (Environment)
- Dr Clive Tilluckdharry, Specialist Medical Officer and director of the IVCD
- Senior members of the Ministry of Health
- Technical Staff of the Ministry of Health
- UWI staff

Fig. 6.1: Campus Principal, Dr B. Tiwarie (Centre) opening the stakeholder workshop in Trinidad, April 29, 2005. To the left of the Principal are Dr G Sirju-Charran, Head of the Dept. of Life Sciences, and Dr D. Narinesingh, Dean of Sciences.

The Jamaica workshop (Fig. 6.1.2) had over forty five (45) participants, which included:

- The Dean of the Faculty of Pure and Applied Sciences, Professor Ronald Young
- Campus Coordinator, School of Graduate Studies and Research, UWI, Professor Trevor Jackson
- Dr. Elizabeth Ward, Director of Disease Prevention and Control, Ministry of Health
- Meteorologist, Meteorological Services Division, Clifford Mahlung, who is the focal point for the National Communication for Jamaica.
- Lecturer, Department of Life Sciences, Dr. Dwight Robinson
- Senior members of the Ministry of Health
- Technical Staff of the Ministry of Health
- UWI staff
- Project Staff

Fig. 6.2: Dr. Elizabeth Ward, Director of Disease Prevention and Control, Ministry of Health, addressing the workshop participants in Jamaica, April 25, 2005

It is believed this high level of attendance and participation signaled the significant level of importance that is ascribed to Dengue Fever in T&T and Jamaica

The Agenda issues included among other items:

- An overview of the AIACC research project on CC and DF in the Caribbean
- Results of the study – Prospective and Retrospective data
- Results of the socioeconomic study conducted in Jamaica
- Results of the Knowledge, Attitude and Practices (KAP) studies regarding Climate change and Dengue Fever in T&T, St Kitts/Nevis and Jamaica
- Climate scenarios – consequences for the Caribbean (Fig. 6.1.3).
- Early Warning System
- Adaptation

There were good lively discussions as to the potential of CC impacts on our every day life, especially the health issues. All the presentations were followed by meaningful discourse, indicating that there was an interest in the emerging issues of climate change.

Following the presentations on "Adaptation Strategies for DF prevention by Dr. Sam Rawlins, the groups were asked to make recommendations for strategies appropriate to Jamaica and Trinidad and Tobago.

Measures for adaptation included use of short-term and long-term strategies, some involving adulticides and larvicides, use of chemical, biological and physical strategies, health promotion with the use of surveillance tools as well as predicting the likely outbreaks of disease and use of an early warning system for the community to minimize disease. Recommendations by workshop participants who returned the questionnaire were summarized to give priorities based on:- cost, effectiveness, social acceptability, environmental appropriateness, effects on neighbours, technical challenges and international dimensions. Based on degrees of high, medium and low, the six responses were analyzed to identify priorities.

Climate issues, which were noteworthy for discussion were:

1. Currently used simple climate-related information for anticipation of DF transmission and Use of an "Early Warning system based on a Moving Average Temperature (MAT)"
2. The currently used climate prediction season – expecting dengue transmission in the wet season (September – November in most Caribbean countries). This coincides with increased number of habitats producing enhanced numbers of vectors. There was a significant level of acceptance (% of respondents giving a "high" level – as opposed to medium or low – of use of this tool) based on the criteria:
    - Cost, Effectiveness, Social acceptability Environmental challenges, Neighbourhood effects- all 67%
    - Technical challenges – 75%.
3. Similarly, the newly espoused system MAT was considered to have a significant degree of "high" recommendations:
    - Effectiveness -67%
    - Social acceptability -57%
    - Environmentally Friendly – 83%
    - Neighbourhood effects – 67%
    - Technical challenges – 100%
    - Cost – 33%.

This perceived relatively low cost for implementation of the MAT and the relatively high degree of technical challenges for introduction of this new system will need to be balanced. These two climate forecasting issues – the traditional and using the MAT will need to be assessed in practical terms and their usefulness as tools for an Early Warning system for Dengue Fever in the Caribbean be evaluated.

The results of the project are to be disseminated to all stakeholders, including those who attended the workshops in the form of (i) CD's of the workshop presentations and (ii) a monograph of the results of the project which can be used for classroom and workshop purposes.

Fig. 6.3: A presentation on scenario generation to the workshop participants in Jamaica

6.2 National Communications

A member of the SIS06 research team, Dr. Amarakoon, participated in the first National Communication from Jamaica. The National Communications focal point for Jamaica, Mr. J. Spooner/Mr. Clifford Mahlung, have been invited to attend our workshops and are well aware of project SIS06. Through them links will be made with other focal points in the Caribbean, so that the results of this project can be made a part of the National Communications for other countries in the Caribbean.

6.3 Science Policy Linkages

Dr. Elizabeth Ward, Director of Disease Prevention and Control, Ministry of Health, Government of Jamaica, who attended the stakeholder workshop would like to implement a simple form of the early warning system for dengue fever and is arranging meeting to follow up.

7 Outputs of the Project

7.1 Papers Published in Peer Reviewed Journals

Abstracts published in peer reviewed journals

1. Rawlins SC, Chen A, Ivey M, Amarkoon D, & Polson K. 2004. The impact of climate change/variability events on the occurrence of dengue fever in parts of the Caribbean: a retrospective study for the period 1980-2002. *West Indian Medical Journal* 53 (Suppl.2).54.
2. Rawlins SC, Chen A, Rawlins JM, Chadee DD, Legall G, 2005. A knowledge, attitude and practices study of the issues of climate change and public health in two Caribbean countries. *West Indian Medical Journal* 54; (Suppl.2): 78-79.

7.2 Other Outputs

Postgraduate thesis submitted

1. Rainaldo Crossbourne, *Developing a Caribbean Climate Interactive Database (CCID)*, in partial fulfillment for the requirements for the M.Phil. Degree (Physics), University of the West Indies, Mona.
2. Charmaine Heslop Thomas, *Vulnerability to dengue fever in Jamaica*, in partial fulfillment for the requirements for the M.Phil. Degree (Geography), University of the West Indies, Mona.

Papers submitted to peer reviewed journal

1. Dave D Chadee, Balkaran Shivnauth, Samuel C. Rawlins and A. Anthony Chen, Climate variability, mosquito density and epidemiology of dengue fever in Trinidad (2002-2004): a prospective study, submitted to American Journal of Tropical Medicine and Hygiene

Invited paper

1. Anthony Chen, A. Amarakoon, Samuel Rawlins, Michael A. Taylor , Dave Chadee, Sherine Huntley, Cassandra Rhoden and Roxanne Stennett, *Climate Change, Dengue and Prevention*, Inter-American Institute for Global Research (IAI) Science Symposium in Montreal, Canada, May 4, 2005.

Papers delivered at conferences

1. Chen, W. Bailey and C. Heslop-Thomas, Human Dimension of Climate Change in the Caribbean-Taking Stock and Moving Forward, Open Meeting of the Human Dimensions of Global Environmental Change Research Community, Montréal, Canada, October 16–18, 2003
2. Dharmaratne Amarakoon, Roxann Stennett, Anthony Chen Climate Variability and Disease Patterns in Two South Eastern Caribbean Countries; Proceedings of the Caribbean Environmental Fourm-2 (CEF-2); Trinidad, May 31-June 4, 2004.
3. Charmaine Heslop-Thomas and Wilma Bailey, *Dengue and climate change in Jamaica*, 30th Congress of the International Geographical Union, Scotland, August 15-20, 2004. (Presented by Elizabeth Thomas Hope)
4. Roxann Stennett, A.M.D. Amarakoon, Anthony Chen, *Association of Dengue Fever with Climate in the Caribbean*, Seventh Bi-annual Conference of the Faculty of Pure and Applied Sciences, University of the West Indies, Mona, May 17-19, 2005

Posters presented at conferences

1. Rainaldo Crossbourne, *Developing a Caribbean Climate Interactive Database (CCID)*, Pure and Applied Sciences Bi-annual Conference 2003, University of the West Indies, Mona
2. A.M.D. Amarakoon, A. Chen, S. Rawlins, R. Stennett, M. Taylor, *Dengue epidemics-its association with precipitation and temperature, and its seasonality in some Caribbean countries*; 49th Annual CHRC

(Caribbean Health Research Council) conference; Grenada, April 21-24, 2004. Abstract published in West Indian Medical Journal Supplement, 53(2), p60, 2004.

3. Cassandra Rhoden, A.Anthony Chen and Michael Taylor, *Scenario Generation of Precipitation and Temperature for the Caribbean*, Seventh Bi-annual Conference of the Faculty of Pure and Applied Sciences, University of the West Indies, Mona, May 17-19, 2005

4. Dharmaratne Amarakoon, Tannecia Stephenson, Anthony Chen, Michael Taylor, Roxann Stennett, Charmaine Heslop Thomas, Wilma Bailey, Samuel Rawlins, Dave Chadee, *Associations of climate with dengue in the Caribbean,* Wengen Workshop on Global Change Research (Climate, Climate Change and its Impacts on Human Health); 10th Anniversary Meeting; Wengen (Bernese Alps) Switzerland, September 12-14, 2005

Papers in other journals

1. Dharmaratne Amarakoon, Anthony Chen, Samuel Rawlins, Michael Taylor, *Climate Variability and Patterns of Dengue in the Caribbean*: AIACC Notes, 2(2), p.8, November 2003.

2. Charmaine Heslop-Thomas, Wilma Bailey, Dharmaratne Amarakoon. Anthony Chen, Samuel Rawlins, David Chadee, Rainaldo Crosbourne, Albert Owino, Karen Polson, Cassandra Rhoden, Roxanne Stennett, Michael Taylor, *Vulnerability to Dengue Fever in Jamaica*, AIACC Vulnerability Synthesis Volume.

3. Taylor, M. A., Chen, A. A., S. Rawlins, C. Heslop-Thomas, A. Amarakoon, W.Bailey, D. Chadee, S. Huntley, *Adaptation strategies for present and increased future risk of dengue fever in the Caribbean*, AIACC Adaptation Synthesis Volume.

Caribbean Climate Interactive Database (CCID)

This is described in Chapter 2; resides at, and is maintained by, the University of the West Indies, Mona. The contact person is Dr. Michael Taylor (michael.taylor@uwimona.edu.jm)

7.3 Works in Preparation

1. Chen, A., S. Rawlins and C. Chadee (eds), *Climate change, dengue fever and prevention*, a monograph to be ready in approximately 1 month. (To obtain copies please contact anthony.chen@uwimona.edu.jm)

2. *CD's of presentations at stakeholder workshop*, ready and to be distributed with monograph (To obtain copies please contact anthony.chen@uwimona.edu.jm)

3. Dharmaratne Amarakoon, Anthony Chen, Samuel Rawlins, Michael Taylor, Roxanne Stennett, *Climate and Dengue in the Caribbean – A Useful Temperature Index*, paper to be submitted to J. Climate Change in 2 month

4. Chen, C. Rhoden, M. Taylor, A.M.D. Amarakoon, *Caribbean Climate Scenarios and Early Warning in the Caribbean*, paper to be submitted to Mitigation and Adaptation Strategies for Global Change in 2 months.

5. Cassandra Rhoden, *Generation of Precipitation and Temperature Scenarios for the Caribbean*, Thesis to be submitted by December 2005 in partial fulfillment for the requirements for the M.Phil. Degree (Physics), University of the West Indies, Mona.

6. Roxanne Stennett, *The Study of Climate Variability and its Impact on Dengue for the Caribbean,* Thesis to be submitted by December 2005 in partial fulfillment for the requirements for the M.Phil. Degree (Physics), University of the West Indies, Mona.

7.4 On Going Work

1. Sherine Huntley, Ph.D. project on Pupal survey and transmission thresholds at the University of the West Indies, Mona, Jamaica

2. Karen Ploson, Ph. D. project on Laboratory Studies on the effect of temperature on the dengue vector at the University of the West Indies, St. Augustine, Trinidad.

8 Policy Implications and Future Directions

Results of this project (Chapter 2) show that an increase of about 2 ºC can be expected in the Caribbean by the end of the century. Based on epidemiology studies cited in this report (Chapter 1) and the association found between dengue and climate in this study (Chapter 3), disease transmission of dengue fever is expected to increase 3 fold due this temperature increase. Results show that there is uncertainty about precipitation changes, but this is immaterial to the spread of the disease as noted earlier. Because the Caribbean population has been exposed to all strains of the dengue fever, the risk of potentially fatal dengue hemorrhagic fever (DHF) is high. The results of this study therefore should not be taken lightly, even if dengue fever is currently classified as a class II disease. In fact there have been serious outbreaks in Cuba (1981) and in Venezuela (1989-90).

In Chapter 4 we have identified deficits in current adaptation strategies for preventing dengue outbreaks, and in chapter 3 we have examined some of the reasons for this deficit. To remedy this situation we have recommended strategies for adaptation ranging from simple to more complex (Chapter 4).

This project has therefore laid the foundation for providing the basic inputs for decision making. By disseminating information about the results of this project, mainly in the form of workshops for stakeholder, to be followed by a monograph and CD of our results and recommendation, we hope to impress on policy makers the need to implement these recommendations. At the same time we realize that this will be very difficult because (i) politicians are concerned with short term processes, and (ii) many of the countries of the Caribbean are financially strapped. In addition most decision makers and planners in the climate change arena are more concerned with sea level rise (Chapter 3), the threat of which is certainly not as imminent as that of dengue fever.

There are also other climate change issues to be deal with. Firstly, scenario generation by statistical downscaling is not sufficient. The use of regional dynamic models to complement and supplement statistical downscaling is necessary to reduce uncertainties in scenarios. Other problems associated with temperature increases need to be looked at. These include other climate induced disease such as asthma, other vector borne diseases and the effects of high temperature on coral reefs.

It is hoped that collaborative research on climate change will still continue even though the project is over, so that there will always exist a body of researchers whose presence will be felt in climate change issues by enlightening and enlivening discussions on the subject, and who can be called upon to provide the necessary input to decision making. These researchers will provide the expertise in determining the level of reliability or uncertainty of the climate change projection, the severity and spatial extent of the threat, the adaptation strategies to be employed and the projected outcome. Decisions makers must consider all these inputs as well as others, such as those related to economic considerations, in arriving at decisions on adaptation strategies. Hopefully, through this project and others, the stage in the Caribbean will soon be reached where climate change issues will become more of a concern.

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