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Adapting to Dengue Risk—What to do?[1]

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1. Dengue—A Caribbean Health Problem

To have ever been inflicted with dengue fever is to know that illness begins with a high fever, severe headache, pain behind the eyes, and muscle and joint pain. This may be accompanied by nausea, vomiting, loss of appetite, and the appearance of a rash 3–4 days after disease onset. In its most severe form, the disease progresses to dengue hemorrhagic fever (DHF), characterized by internal bleeding, which can prove fatal, particularly for children and young adults.

Dengue fever has been reported in the Caribbean for well over 200 years (Ehrekranz et al., 1971), although the interval between epidemics has decreased sharply since 1970. Epidemics are partially explained by the introduction or reintroduction of dengue serotypes as was the case in 1977. In that year, dengue-1 re-emerged in the Caribbean, and a devastating pandemic followed which lasted until 1980 (Pan American Health Organization (PAHO), 1997). Similarly, in 1981, the dengue-4 strain emerged in

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the Americas, so that currently all four dengue serotypes can be found in the region (Rawlins, 1999).

Since 1981, however, the number of recorded cases of the disease has continued to increase (Figure 1) and drastically so since 1991. Between 1981 and 1996, 42,246 cases of DHF and 582 deaths were reported by twenty-five countries in the Caribbean and wider Americas (Caribbean Epidemiological Centre (CAREC), 1997). The impact of an epidemic can be devastating as illustrated by the first major outbreak of DHF in the Americas, which occurred in Cuba in 1981 (CAREC, 1997). During that outbreak, 344,203 dengue cases were recorded, of which 10,312 were classified as severe (World Health Organization, (WHO), grades II-IV), and 158 were fatal.

The factors that influence dengue outbreaks are numerous, including the presence of the disease in a territory, the immunity of the population and socio-economic conditions that impact (among other things) vulnerability and the ability of the disease to spread and do so quickly. There is, however, no potential lack of epidemic sources given the significant increase in the free movement of the region's populace between and beyond Caribbean borders and the fact that a recovered dengue sufferer forever remains a host for the virus. The reintroduction of dengue-1 in the region in 1977 was initially detected in Jamaica, from where it spread to virtually all other islands of the Caribbean.

It is other factors such as vector abundance and the frequency of vector-human contact that provide reason to believe that the risk of dengue epidemics is increasing with climate change, and it will continue to do so should climate change itself accelerate. Dengue is a vector-borne disease and (much like the disease) the vector—the *Aedes aegypti* mosquito—is virtually omnipresent throughout the region. Changes in the life cycle of the virus, which lead to increased vector-human contact are linked to warmer temperatures, whereas both an excess of or lack of rain can contribute to an increase in breeding sites and vector abundance. (Excess rainfall results in pools of stagnant water, whereas a lack of rainfall encourages water storage). Variability in these two climate stimuli, that is, temperature and rainfall, likely accounts for some of the pattern of outbreaks seen since 1981 (Figure 1), and further changes in both variables, for example, a warmer wetter scenario would similarly influence future outbreaks.

The public health programs of the region, therefore, face a double jeopardy, as at their current level and style of operation, they have a deficit that seems certain to increase with the onset and acceleration of climate change. In this chapter, the problem of adaptation to the threat of present and increased future risk of dengue fever due to climate change is examined. To do so, the dengue-climate link is first explored to see whether the past suggests that the perceived future threat is real. Thereafter, the effectiveness of current adaptive strategies to contain dengue at present risk levels is assessed, as is the extent to which they target the most vulnerable. We also hypothesize about the ability of the utilized strategies to cope with the possible increased risks and suggest options, within the constraints of the Caribbean reality, for expanding, strengthening or combining existing programs or implementing new ones to better respond to the challenge of increased risk. This chapter draws on results from a study entitled: "The Threat of Dengue Fever—Assessments of Impacts and Adaptation to Climate Change in Human Health in the Caribbean."

2. Data and Methodology

Dengue records were provided by the Caribbean Epidemiological Center (CAREC), which is a storehouse for epidemiological data from the English-speaking Caribbean. Cases were reported on a weekly, monthly, and/or annual basis. Climate data were from the Workshop database of the Climate Studies Group, Mona (CSGM) and consisted of daily and monthly station data (maximum and minimum temperature, and rainfall) for twenty-seven Caribbean territories, as provided by their respective meteorological services. The study period was 1980–2001 and was defined by data availability. Statistical analysis of the climate and dengue incidence data was used to indicate associations between the variables and to identify target countries for detailed analysis.

The identification of vulnerable subgroups within target countries and the isolating of common characteristics among the subgroups were done using geographic and socio-economic data and appropriate survey instruments. The identification and classification of adaptive strategies were done in collaboration with CAREC and the health ministries of the target countries, and matrix analysis was used to examine their characteristics and constraints. The identification of a limited best set of practices is done via expert judgment, and it is from these that we recommend a course of action to be considered as the basis for policy change within the region.

3. Dengue and Climate—A Cause for Concern

Figure 2 indicates that there is a clear seasonality to dengue outbreaks within the Caribbean. The pattern shown for Trinidad can be generalized for the entire basin, with outbreaks peaking toward the end of the year[2]. On average, outbreaks lag the second and principal maximum in rainfall by 3–4 weeks and the maximum in temperatures by 6–7 weeks. Similar observations have been noted in studies done for Trinidad and Tobago (Campione-Piccardo et al., 2003; Wegbreit, 1997) and for Barbados (Depradine and Lovell, 2004). The climatological sequence is therefore: warm temperatures (with the climatological maximum being attained) → abundant rainfall (in most cases the demise of the late rainfall season has begun) → dengue outbreaks.

Statistically significant lag correlations between weekly dengue cases and temperature and precipitation in given years confirm the climate associations, with the temperature relationship being stronger. Strong associations with temperature are not unexpected, as studies by Koopman et al. (1991), Focks et al. (1995), and Hales et al. (1996) suggest that there is a shortening of the extrinsic incubation period of the dengue parasite within the mosquito (i.e., a shortening of the interval between the acquisition of the infectious agent by the vector and the vector's ability to transmit it to other susceptible vertebrate hosts) with warmer temperatures (Hales et al., 1996). There is also an increase in blood meals (McDonald, 1957). Vector-human contact therefore increases with warmer temperatures. The linear associations with rainfall (though weaker) are also not unexpected, as both an excess and lack of rainfall can contribute to increased vector abundance due to water storage (deliberate or otherwise). Note, however, that the link between rainfall availability and vector abundance is not to be dismissed, and rainfall variability is a stress that must be monitored and/or accounted for in adaptation strategies.

Figure 1 also indicates that, in addition to the seasonality, there are changes on longer timescales, as well an interannual variability in the number of cases reported in the Caribbean. Reported cases have increased dramatically in the 1990s, and there is marked variability from year to year superimposed on the increase. Stratifying dengue epidemics according to ENSO phases reveals a bias for El Niño or El Niño+1 years (Amarakoon et al., 2003), which is captured in Table 1. Similar links between upsurges of dengue fever and ENSO events have been noted for the south Pacific (Hales et al., 1996) and Colombia (including its Caribbean coast) (Poveda et al., 2000). We also find significant results when four weekly cases are reported and monthly temperatures are correlated over the period under analysis, with the correlations increasing if El Niño and El Niño+1 years are isolated. (Correlations are again weaker and insignificant with rainfall).

We suggest that the link with ENSO events results from the latter's impact on both the temperature and rainfall regimes of the Caribbean. The rainy season is drier and hotter during El Niño occurrences, with warmer temperatures continuing into the El Niño+1 year (Chen and Taylor, 2002; Taylor et al., 2002). The early part of the rainy season also tends to have wetter than normal conditions during the El Nino+1 year (Taylor et al. 2002).

In tandem, all of the above suggests genuine cause for concern within the region. Regional temperatures (maximum and minimum) have increased over the past 40 years (Peterson et al., 2002; Taylor et al. 2002) and are projected to continue doing so in the near future. Projections for 2080 suggest a Caribbean, which is warmer by 2 or 3^{o}C (Santer, 2001), with statistical downscaling confirming increases of this magnitude for Trinidad and Tobago, Jamaica and Barbados (Rhoden et al. 2005). Additionally, although it is unclear how the El Niño phenomenon will respond to climate change, some models indicate an increase in event frequency in a world forced by future greenhouse warming (Timmermann et al., 1999). Both the projected temperature increases and the possible increase in El Niño frequency would impose additional stress on an already fragile and vulnerable health system by favoring increased vector abundance and vector-human contact.

4. Retirement, Pitfour and John's Hall—Profiles of Vulnerable Communities

In arguing then for appropriate adaptation strategies, it is to be remembered that effective strategies must target the most vulnerable. In the Caribbean, vulnerability to dengue fever is largely conditioned by socio-economic circumstances. To isolate common characteristics of the most vulnerable to dengue fever, a local level study was done for a section of the parish of St. James in western Jamaica, based on the pattern of dengue occurrences in 1998 (Heslop-Thomas et al., 2005). For that year, there was a concentration of cases within the capital city of Montego Bay and sporadic cases that followed a permanent stream with associated seasonal streams and gully banks. Three communities (Table 2) were selected along this hydrological feature, and a questionnaire was administered to a 10% sample of heads of households. The questionnaire solicited information on socio-economic conditions, support systems, knowledge of the disease, and cultural practices that might have implications for the spread of dengue fever.

Responses given in the questionnaire survey were used to construct a vulnerability index based on a number of indicators identified in the literature. The vulnerability indicators included herd immunity, knowledge of the symptoms and vectors of disease, the use of protective measures, source of water and water storage devices, distance from the nearest health facility, chronic illnesses, and measures of resilience and stress—education, employment, income, female household headship, room densities, coping strategies, integration into the community. The index was determined for the community and for the surveyed households, and subgroups created of the most and least vulnerable within each community.

Significant results from the assessment of index values and survey responses were as follows:

1. Seventy-eight percent of the respondents felt that dengue control should be the responsibility of the government. This view contrasted sharply with that of the Jamaican Ministry of Health, which saw dengue control as the responsibility of communities. More than a one-half of those interviewed in the communities also could not say what causes dengue fever, and the overwhelming majority had no knowledge of its symptoms.

2. Like poverty, vulnerability increased outward from the urban area. The most vulnerable subgroups comprised 14% of the entire sample and had largest representation in John's Hall and Granville/Pitfour—the two communities with squatter settlements. Outstanding characteristics of the most vulnerable group were 95% of the household heads had no skills; 87% earned the minimum wage or less and 84% were female heads. The least vulnerable comprised that sector of the urban community that was employed (97%), possessed marketable skills (78%), and earned wages that were above the national minimum (81%).

3. Households in which there is no piped water are more at risk as water storage becomes necessary. In the three communities, 23% had no access to piped water in their homes or yards, and all respondents said that the supply of water was irregular. Fifty-four percent of the respondents stored water in drums, which in most cases were uncovered to facilitate the catching of rain water and/or easy

access to the stored water. The outdoor drum is one of the most productive *Aedes* breeding containers (Focks and Chadee, 1997). Significantly, 97% of the least vulnerable subgroup had water piped into their dwellings.

In summary, the study suggested that the most vulnerable were the poor, who lived in informal or squatter settlements and who as a result lacked basic community infrastructure, including access to piped water and adequate garbage disposal. They also lacked the community structure to facilitate collective action on any issue, including the threat of a dengue fever outbreak. They were also to a large extent unaware of the cause of dengue fever and how their actions might contribute to the disease and felt that it was the responsibility of the government to contain the disease or any threat of its outbreak.

5. Current Adaptation Strategies Assessed

There is a marked similarity in the adopted strategies for handling dengue fever in the islands of the English-speaking Caribbean. This is probably due in part to a common heritage, which has led to common social structures, the active involvement of the PAHO/WHO in supporting anti-dengue programs in member countries, and the work of CAREC in defining regional strategies. Because of the similarities, it is possible to generalize about the strategies used, highlighting, whereever 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 data set, 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 under each heading for both countries 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, the description of symptoms, and disease treatment. Although both health ministries possess education and promotion units, neither has staff dedicated to dengue fever, nor do they make use of the media before the occurrence of an outbreak. Effectiveness of promotion strategies is 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 quarterly 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 and treating breeding sites, as well as recording epidemiologically important indicators such as vector abundance—adult, larval, or pupal—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 of an appropriate insecticide. Although 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 limited to areas where outbreaks have occurred or where risk is high because of 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 use of physical methods such as the installation of mesh screens on buildings. In Jamaica, there is no sustained program aimed at the reduction of larval or pupal abundance, although on request there is limited chemical control through the use of Abate granules. In Trinidad and Tobago, inspectors from the surveillance unit carry a supply of temephos (Abate) for the active treatment of breeding places on discovery.

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, for example, 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 centers offering different levels of care. There is a health centre within 5 miles of every community, and the decentralization of health services has 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 epidemics of diseases.

In summary, the current adaptive strategies do nothing to address the issues of the most vulnerable, that is, 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 also do nothing to rally or facilitate collective action, nor do they assist in transferring responsibility from governments to communities.

6. Adaptation Options Assessed

In Table 2, 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 that 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 a best guess (expert opinion) and are guided by the views and knowledge of the region's environmental health officers. The assessment characteristics are (1) cost to implement (2) effectiveness (as measured by its long-term ability to reduce risk or address vulnerability) (3) social acceptability, (4) environmental friendliness, (5) promotion of neighborliness, and (6) 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 (1) and (6) in which 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, that is, whether their intent is to immediately alleviate the threat associated with dengue fever or to do so gradually.

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 an appropriate insecticide (fogging). Of the three, public education achieved the highest composite score, whereas adulticidal fogging achieved the lowest score. Education benefits from the fact that in the present framework, it is generally medium to high ranked in each category. Its effectiveness is medium ranked because of the seasonal nature of the campaign, whereas the presence of established units to handle education accounts for the medium (as opposed to high) ranking with respect to cost and technical challenges. Insecticidal fogging, though oft demanded and practiced, suffers from limited long-term effectiveness, an inability to promote neighborliness (people shut their windows), limited social acceptability (as the often-used insecticide—malathion—has a characteristically unpleasant odor, and there is the need for specialized equipment for its distribution).

Of the long-term strategies assessed, the education strategies again achieve highest composite ranking (though only marginally so), with the focus being on sustained campaigns 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 are 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. Even then, much would depend on householders being vigilant in covering containers. 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, for example, using fish to control mosquito population is an environmentally friendly option, but it is not suited for community practice unless the community could be persuaded of the benefits of proper implementation. 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.

7. Best Practices Recommendations

No single "best" adaptation option exists to counteract the threat of increasing dengue fever within the Caribbean. As suggested by Table 3, the variety of strategies has 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 3 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 facilitate 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 in Section 5 are at least maintained.

7.1 Option 1—Refocusing Current Strategies

Option 1 advocates that currently used 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 a slant, however, 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 before the rainy season through organized activities in nearby churches, schools, youth, and service clubs and using competitions to test knowledge and community cleanliness. Involvement before dengue onset would promote long-term behavioral change (not just a dengue season problem) and community responsibility. Behavioral change strategies have been advocated by WHO as an important mechanism for prevention and control of dengue fever (WHO, 2000), and community mobilization has shown recent success in reducing cases of dengue fever during outbreak (WHO, 2005). 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.

7.2 Option 2—Plus Proper Water Storage

Option 1 does not address the vulnerability issues surrounding proper water storage. The proposed adaptation strategies in Table 2 (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 that 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 used 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, for example, subsidies and an intensive public education undertaken emphasizing the value of the drums/drum covers. Incentives may also have to be given to cover the drums, that is, despite the presence of the drum covers, whereas efforts would also have to be made to ensure that other habitats are made vector-free.

7.3 Option 3—Plus An Early Warning System

Like option 1, 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 3 and would involve multisectorial cooperation. Monitoring of climatic indices would be undertaken by the meteorological services, the regional universities and/or the regional climate research institutes. The information would then be used as the basis for issuing an alert or *watch*. On this basis, the frequency of surveillance would be altered and the education campaign tailored to meet the level of perceived threat. If surveillance data confirm the presence of the pathogen or an increase in its abundance, subsequent warnings could be issued as needed. A benefit of this multistaged early warning approach is that response plans can be gradually ramped up (e.g., the inclusion of other strategies such as chemical or biological control) as forecast certainty increases. This would give public health officials several opportunities to weigh the costs of response actions against the risk posed to the public.

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. A framework for a health early warning system (similar to that proposed in Figure 3) is given by the National Research Council report. (U.S. National Research Council, 2001).

8. Conclusions

From 1991 onward, there has been a significant increase in dengue cases in the Caribbean, and presently there is concurrent circulation of all four 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 a 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 population to dengue outbreaks is 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.

Admittedly, however, even if proper water storage facilities are provided, there is still the uphill task of convincing people to remove the additional breeding sites available in the vicinity of residences, including pools of water in old tires, at the base of plant pots and in other domestic receptacles left lying around. Consequently, of the three adaptation options offered (see again the previous section), the implementation of an early warning system might hold significant potential. As its basis, option 3 suggests that it might be possible to achieve behavioral change on an emergency basis that cannot be induced on an everyday basis. Because it is possible to predict outbreaks on the basis of El Niño events, public health authorities could try issuing emergency warnings and urging prompt action for a short period during the El Niño periods that are favorable to vectors. If this temporary behavior change is successful, it may eventually become widespread and permanent. Over time, option 3 would then facilitate the transfer of information, the transformation of behavioral practices, (hopefully) the engendering of community spirit and action, and the gradual shift of responsibility for alleviating the dengue threat to government-community partnerships. Of course, it remains to persuade the meteorological services and the public health authorities to cooperate in this fashion.

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.

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End Notes

1. Dengue 2 and dengue 3 were previously introduced during the early 1950s (Downs, 1964) and 1960s (Ehrekranz et al., 1971), respectively.
2. The Trinidad data also show a bimodality to the dengue case pattern, which, however, is not consistent in other territories.

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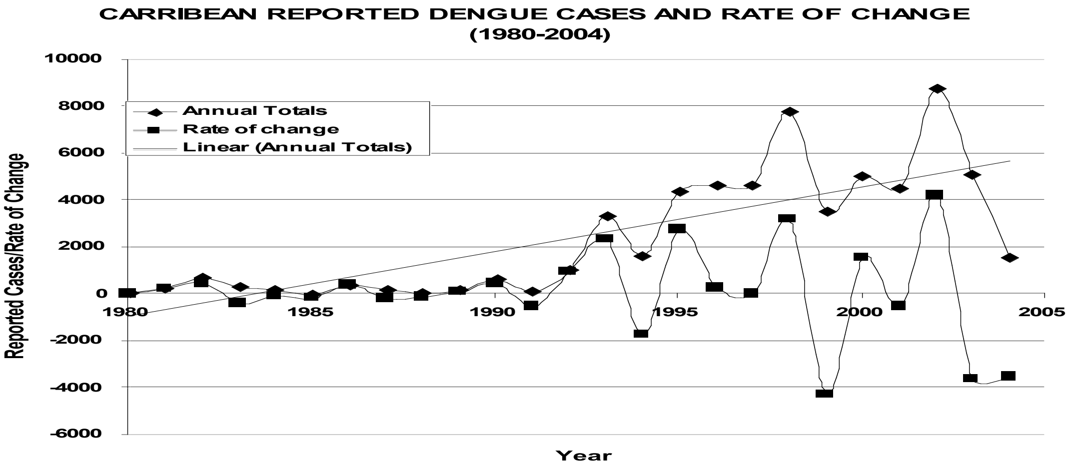

Figure 1. Annual variability of the reported cases of dengue and the rate of increase for the Caribbean.

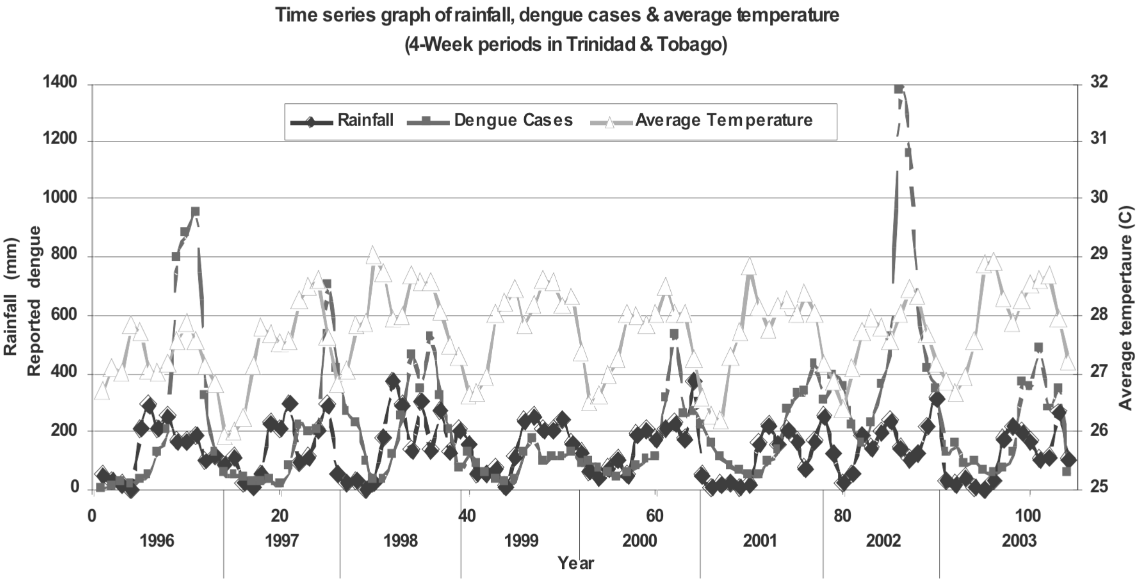

Figure 2. Monthly variability of the reported dengue cases, rainfall, and temperature from 1996 to 2003 in Trinidad and Tobago.

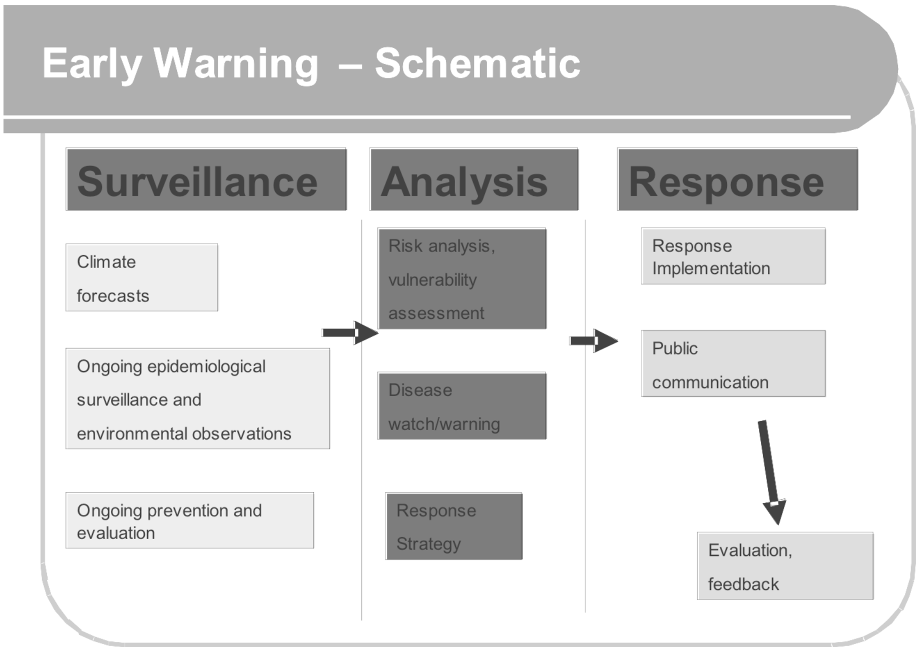

Figure 3. Schematic of possible early warning system

Table 1. *Distribution of Epidemic Peaks Among ENSO Phases (1980–2001)*

Region	**Total**	**El Niño and El Niño+1**	**La Niña**	**Neutral**
Caribbean	8	7	-	1
Trinidad & Tobago	8	6	-	2
Barbados	6	5	-	1
Jamaica	5	4	-	1

Table 2. *Socio-Economic Characteristics of Three Communities in Western Jamaica and Survey Sample Size*

	Granville/Pitfour	**Retirement**	**John's Hall**
No. of households	1,507	485	572
Infrastructure	Mixture of formal and informal structures. Ratio (50:50)	Few informal dwellings	Rural squatters
Economic bracket	Low income Heads of families self employed or in the service sector in Montego Bay.	Lower middle income Heads of families in the service or public sector in Montego Bay	Poor Rural squatters. Primarily female heads of household engaged in domestic service or petty trading.
Sample/households	151	49	57

Table 3. *Adaptation Strategies Matrix*

Measures	Cost	Effectiveness	Social Acceptability	Friendly for Environment	Neighbor 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

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.