Dengue, Aedes aegypti, and Hurricane Reconstruction in The Caribbean and Central America: Prevention and Control Following a Natural Disaster

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Preface:
Dengue is currently the most important vector-borne viral disease affecting people, in terms of both morbidity and mortality. Repeated epidemics of dengue and dengue hemorrhagic fever afflicting millions of individuals occur annually in tropical and subtropical areas of the world, including The Caribbean and Central America, inhabited by the *Aedes aegypti* mosquito.

Accordingly, the main purpose of this study was to identify and address the dominating factors influencing the resurgence of dengue fever following a natural disaster such as a hurricane.

This study also depicted an arguable approach to dengue surveillance as well as described existing efforts to prevent, control and eradicate dengue (*Aedes aegypti*) with the aim of detailing potential problems that must be addressed to prevent further dengue fever outbreaks.

Virologic surveillance should be consider the most important element in any such early warning system. Dengue virus transmission should be monitored to determine which serotypes are present, their distribution, and the type of illnesses associated with each. Effective dengue surveillance can provide an early warning capability permitting emergency mosquito control measures to be implemented and major epidemics to be averted.

Dengue prevention and control programs must be in line with more effective surveillance as an early warning system that can predict epidemic dengue, and combining this with mosquito control measures - including community-based measures - to reduce *Aedes aegypti* densities.

An effective dengue surveillance system must address the disease from both a clinical and an entomological perspective as well as consider the virologic, epidemiologic, and serologic aspects.

Learning Objectives: Upon completion of this presentation, the learner should be able to:

1. Examine and explain the growing significance of disaster mitigation and strengthening regional surveillance networks for dengue and dengue hemorrhagic fever following a natural disaster (e.g., hurricane).
(2) Define how to strengthen the regional capacity for effective implementation of prevention and control strategies for disaster mitigation.

(3) Emphasizes the practical application of field research in the management and control of the dengue vector, Aedes aegypti, following a natural disaster as well as promoting the further development of applied research in the areas of rapid diagnosis, epidemiology, and prevention.

(4) Describe an interdisciplinary team approach to achieving success with prevention and control programs. Emphasizing national and regional infrastructures for early warning of and rapid response to infectious disease threats, following natural disasters, through laboratory enhancement.

Keywords: Disasters, Infectious Diseases, Dengue, Aedes aegypti, Hurricane/Tropical Storms, Prevention and Control

Related Web pages on "Dengue, Aedes aegypti, and Hurricane Reconstruction in The Caribbean and Central America: Prevention and Control Following a Natural Disaster" follow below:

Slide presentation:

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**INTRODUCTION**

Hurricanes have proven to be a very calamitous and costly natural disaster for The Caribbean and Central America. Unrelenting rains and savage winds, which accompany hurricanes, produce devastating mudslides and sustained flooding. In the wake of hurricanes, thousands of inhabitants face the plight of a greatly diminished capacity to go about their daily lives as a result of destroyed or severely-damaged homes, deteriorated living conditions, and increased health risks. Hurricanes inevitably aggravate the frail health of an already vulnerable segment of the population living both in and outside its destructive path. Its most critical impact is evident in terms of seriously deteriorated environmental health conditions, the limited availability of potable water and sanitation facilities, and reduced local capability to provide basic health services.

Dengue is currently the most important vector-borne viral disease affecting people, in terms of both morbidity and mortality. Repeated epidemics of dengue and dengue hemorrhagic fever afflicting millions of individuals occur annually in tropical and subtropical areas of the world, including The Caribbean and Central America, inhabited by the *Aedes aegypti* mosquito. Moreover, the ongoing resurgence of *Aedes aegypti*, following a hurricane, has led to hyperendemicity, more frequent dengue epidemics, and the emergence of dengue hemorrhagic fever/dengue shock syndrome.

Accordingly, the main purpose of this study was to identify and address the dominating factors influencing the resurgence of dengue fever following a natural disaster such as a hurricane. This study also depicted an arguable approach to dengue surveillance as well as described existing efforts to prevent, control and eradicate dengue (*Aedes aegypti*) with the aim of detailing potential problems that must be addressed to prevent further dengue fever outbreaks. Virologic surveillance should be consider the most important element in any such early warning system. Dengue virus transmission should be monitored to determine which serotypes are present, their distribution, and the type of illnesses associated with each. Effective dengue surveillance can provide an early warning capability permitting emergency mosquito control measures to be implemented and major epidemics to be averted following a hurricane. A surveillance system must be simple, yet comprehensive, in its structure and in its operation and flexible enough to allow the incorporation of new data. Dengue prevention and control programs must be in line with more effective surveillance as an early warning system that can predict epidemic dengue, and combining this with mosquito control measures - including community-based measures - to reduce *Aedes aegypti* densities. An effective dengue surveillance system must address the disease from both a clinical and an entomological perspective as well as consider the virologic, epidemiologic, and serologic aspects that are useful in an active surveillance system.
SIGNIFICANCE and PURPOSE of the STUDY
The geographic dissemination and endemic maintenance of dengue depends on the continued introduction of virus into susceptible human populations, spread within these populations, and low-level transmission during non-epidemic periods. Continued dengue transmission represents a public health burden both in terms of costs of dengue control as well as the potentially severe consequences of a dengue hemorrhagic fever epidemic. The increased disease incidence in the Americas, combined with increased frequency of epidemic dengue caused by multiple virus serotypes, has increased the risk of epidemic dengue hemorrhagic fever, one of the leading causes of hospitalization and death among children in Southeast-Asia.

Presently, the only way to reduce the incidence of dengue and thus prevent epidemic dengue hemorrhagic fever is to control the mosquito that transmits the virus. Unfortunately, the ability to control *Aedes aegypti* is limited, and it has been noted in the literature that the only effective way to control the mosquito vectors of dengue is source reduction. The underlying principle of source reduction consists of the elimination or reduction of vector breeding sources in order to disrupt the immature life cycle of the mosquito.

Hurricanes have disrupted the implementation of ongoing dengue vector (*Aedes aegypti*) control activities and, as a result of the tropical storms that accompany hurricanes, fostered the creation of new habitats and optimal conditions in which *Aedes aegypti*, the principal mosquito-vector of dengue virus, multiply. New vector habitats are established due to stagnant water accumulation in uncovered natural and man-made containers and earthen pools that are carved out by the flooding from the storms. In many parts of The Caribbean and Central America, dengue fever is reemerging as a significant public health problem. Although increased incidence is apparent, the extent and causes of the increase have not been adequately documented. Natural disasters, such as hurricanes, make an already bad situation worse, creating greater vulnerability to dengue hemorrhagic fever and mortality.

The region's capacity to control vector-borne diseases appears to have weakened, in part due to the lack of an established system for gathering, storing, processing and interpreting epidemiological data and diagnostic and laboratory capability to generate reliable data. Further complicating the diminished capacity to control vector-borne diseases, is an elevated risk of dengue epidemics as well as dengue hemorrhagic fever following a hurricane. In sum, natural disasters such as a hurricane inevitably cause the disruption of vector control programs and the creation of new mosquito habitats, further elevating the risk of dengue transmission. Health risks due to dengue fever can be substantially reduced through improved surveillance and community-based prevention and control programs.

Given these challenges the communities might face in ensuring that an adequate and effective dengue prevention and control program is in place, the full support and resources of the local, national and international governmental public health agencies will be critical to permit the implementation of an effective operational system for dengue surveillance. Thereby, helping to reestablish, enhance and strengthen the dengue monitoring and surveillance capabilities of the public health agencies of The Caribbean and Central America and protecting their citizens from post-hurricane related health risks.
METHODOLOGY FOR PREVENTION AND CONTROL

A region-wide dengue surveillance and control program is essential in order to enable health authorities to make critical decisions and hence, to reduce response time and minimize morbidity and mortality following a hurricane. Except in those regions where *Aedes aegypti* eradication might still be achievable, the program strategy should be changed from one of eradication to one of control that is based on the actions outlined below:

- The distribution of *Aedes aegypti* must be determined in all regions, especially in the urban areas;

- The status of *Aedes albopictus*, a second very efficient vector should also be determined by intensifying surveillance programs to prevent the spread of this potential vector of dengue virus;

- Emphasizing environmental management as the main vector control tool. The prudent use of insecticides should only be undertaken when physical methods are impractical and biological control methods should only be pursued if appropriate. The prudent use of insecticide should include both space spraying for rapid/temporary reduction of infected adult mosquitoes and source reduction for permanent control plus monitoring vector susceptibility to the insecticides to be used during these periods;

- Continuing to monitor the vector population through appropriate statistical sampling procedures, in order to target control efforts and evaluate control interventions;

- Encouraging and incorporating the community's full participation in the design, execution, and evaluation of prevention and control activities;

- Developing a laboratory-based surveillance network within individual countries or among neighboring countries. Viral isolation capability also should be developed where possible;

- Promoting the public health and medical education of health care personnel in the recognition, management, and treatment of dengue and dengue hemorrhagic fever/dengue shock syndrome;

- Determining the important geographical epidemiologic, and socio-demographic risk factors for dengue, and stratifying the infested areas by level of risk, in order to efficiently utilize available resources;

- Utilizing information systems that integrate all pertinent data on the vector, disease, and risk factors: to aid in decision-making, improve the program, and provide future direction for the program; and

- Periodically evaluating the cost-efficiency and effectiveness of prevention and control programs as a basis for adjusting program strategies.
Ultimately, this study will help to improve the infectious disease surveillance of the affected countries and will enhance their health authorities' capability to monitor and assess the epidemiologic situation by strengthening its overall disease surveillance and health information systems by:

- Providing assistance to establish systems for gathering, storing, processing and interpreting epidemiological data;
- Enhancing diagnostic and laboratory capability to generate reliable data; and
- Develop communication systems to assure dependable lines of communication in future disasters.

A REGIONAL APPROACH TO PREVENTION AND CONTROL
A region-wide integration of a dengue surveillance and control program can bring countries together to address cross-border dimensions of natural disaster mitigation and hurricane reconstruction. A regional approach could streamline cross-border dengue surveillance to provide an early warning capability permitting emergency mosquito control measures to be implemented and major epidemics to be averted following a hurricane. It can help to strengthen transnational linkages, particularly as it relates to information exchange. Lessons learned in one country can be shared across the region, thereby, helping to reduce redundancy. A regional approach not only reduces redundancy but also emphasizes the fundamental need to mitigate disasters and create healthier communities.

This study endeavored to support a collaborative solution regarding a regional approach to a dengue prevention/control and surveillance program which will bring the nations of the region together as equal partners and build upon the assets, strengths, and capacities of each country. Also, to promote and encourage development of improved methods for surveillance and community-based prevention and control programs as well as the communication of the findings and implications throughout the region. However, collaboration must be inclusive to succeed in fostering the equitable exchange of knowledge and ideas between the nations of The Caribbean and Central America.
Hurricanes Mitch and Georges

During the week of October 26, 1998, Hurricane Mitch, one of the strongest and most damaging storms ever to hit the Caribbean and Central America, swept across Honduras, Nicaragua, El Salvador, Guatemala, Belize and Costa Rica. The loss of life and devastation to property from the torrential rains, floods and landslides was enormous. Effects of the natural disaster were intensified by man-made factors. Large-scale deforestation and cultivation of marginal land induced by population pressure triggered massive mudslides. Flooding was exacerbated by lack of adequate watershed management. The rural poor, with limited access to land, often live in marginal high-risk areas, and thus bore the brunt of the effects of the disaster.

Hurricane Mitch resulted in billions of dollars in damages and thousands of lives lost. Flooding and landslides, amplified by poor environmental and land use management, were a main cause of devastation. Hurricane Mitch made clear the interrelationship between management of watersheds’ upper reaches and impacts downstream. The impacts of inappropriate land management, poor agricultural practices, overgrazing, deforestation, poorly sited housing developments, and inadequate pollution control in the upper watershed are manifested in the lower basin by extremes in availability and quality of water supplies, greater vulnerability of populations and economic assets to natural disasters, reduced power-generating capacity due to sedimeted water courses, and damaged coastal ecosystems. Hurricane Mitch also demonstrated the nexus between poverty, environmental degradation, and vulnerability to natural disasters, resulting in yet greater poverty.

According to the United Nations, the loss of life and damage to infrastructure, agricultural commercial and industrial assets has virtually wiped out the development gains of the last 20 years in some areas of the region. Preliminary damage estimates for the region indicated:

- Over 10,000 people dead, 9,000 missing, and 12,000 injured;
- Loss of housing, health facilities and schools estimated at $1.34 billion;
- Damage to water, sanitation and energy infrastructure, roads, bridges and railways estimated at $1.04 billion;
- Loss of productive assets in agricultural, manufacturing and service sectors estimated at $2.91 billion.

It is estimated that Hurricane Georges caused 400 casualties and over $180 million total damage including indirect and secondary losses in Haiti. The perverse synergy of overwhelming poverty, degraded environment, and lack of infrastructure makes Haiti a "disaster-prone" country. Nearly every year large segments of the population suffer from either prolonged drought, frequent floods, or mud slides. An effective reconstruction strategy should deal specifically with increasing local capacity within Haiti to deal with recurring disasters.
Dengue and Aedes aegypti: Prevention and Control Strategy and Objectives

Outbreaks of dengue fever, following a hurricane/tropical storms in The Caribbean and Central American countries may increase the likelihood of future autochthonous transmission. The recent heavy rains and floods have hindered public health control efforts because some areas had been rendered inaccessible for an effective health-needs survey. Moreover, mosquito vectors are widely distributed in these countries and because community public health officials' and physicians' awareness of dengue is low and specialized laboratory diagnostic methods are not available locally, low-level dengue transmission may go undetected. Even though the dengue IgM test is the most appropriate assay for determining current infection, it is not routinely performed and may not be readily available if requested. An educational campaign for health officials and health-care providers and an active laboratory-based surveillance program that facilitated prompt, accurate diagnosis of dengue to assess the risk for local dengue fever transmission should be implemented.

Dengue viruses consist of an antigenic subgroup of four closely related, but antigenically distinct serotypes that can be distinguished by serologic methods and are designated as DEN-1, DEN-2, DEN-3, and DEN-4, which belong to the genus Flavivirus, family Flaviviridae. The spectrum of disease ranges from self-limiting illness to severe disease with complications that may result in death. Primary infection with any serotype may lead to acute illness defined as fever and other symptoms that may subside after 3 or 4 days. The patient may then recover completely, or the fever may return with a rash within 1 to 3 days. The dengue virus persists through a person-Aedes aegypti-person transmission cycle. Following an infective blood meal the mosquito can transmit the virus after a period of 8-12 days of extrinsic incubation.

Aedes aegypti mosquitoes are apparently unaffected by infection with the dengue virus and dengue fever will not shorten its life span nor will it alter its behavior in any detectable manner. However, environmental hazards can determine whether Aedes aegypti will survive long enough to pass-on the dengue virus it carries. Secondary exposure to a different serotype may place the patient at risk for more serious forms of infection, dengue hemorrhagic fever or dengue shock syndrome. The life span of Aedes aegypti, the primary vector of dengue fever is usually 21 days, although life span and incubation periods depend on temperature and rainfall. The mosquito remains infective for life.

The presence of the vector, the rapid spread of the virus, and the increased occurrence of natural disasters will contribute to the possibility of future dengue transmission in this region. An early warning system based on immunoglobulin (Ig)M antibody-capture enzyme-linked immunosorbent assay (MAC-ELISA) laboratory tests should be recommended for disease monitoring. Active surveillance, an essential component of an early warning system for detection of dengue, provides information vital to defining epidemiologic aspects of cases and enabling educational and mosquito control efforts.

There is no specific treatment for dengue fever. Moreover, vaccine development is difficult since any of four different dengue serotypes may cause the disease, and because protection against only one or two of these serotypes might actually increase the risk of more serious disease.
Nevertheless, progress is being made in the development of vaccines that may protect against all four serotypes. At present, the only method of controlling or preventing dengue is to combat the mosquito vector (*Aedes aegypti*) which breeds primarily in man-made containers that retain water. Essential elements of a comprehensive and effective prevention and control program must include:

1. Comprehensive and effective surveillance of vector (*Aedes aegypti*) densities and disease (Dengue) transmission;

2. Developing selective and sustainable vector control programs, including preparedness for emergency control following a natural disaster;

3. Strengthening local capacity for assessment of the social cultural economic and environmental factors that lead to increased vector densities and increased transmission of disease;

4. Mobilization of other community public health sectors to incorporate dengue prevention and control elements in their goals and activities; and

5. Sustained research in vector control utilizing the Internet and satellite imagery.

In sum, dengue fever outbreaks, following a hurricane, in the Caribbean and Central America and the presence of competent mosquito vectors increase the likelihood of future autochthonous transmission in this region. A laboratory-based active surveillance program can detect cases of dengue involving all four dengue serotypes. An active surveillance program can demonstrate that dengue infections are occurring at a much higher rate than reflected by previous passive surveillance programs and this in turn demonstrates that the risk for local dengue transmission may be increasing.

Furthermore, satellite imagery analysis provides an efficient survey of large geographic regions for environmental indicators of disease risk affecting human populations and has the potential to make an effective surveillance of disease risk for vector-borne diseases practical for public health applications. The basis for the supposition that remotely sensed data will be useful for anticipating disease risk is that pathogen transmission is facilitated by arthropods, whose survival and reproduction are influenced by variations in elevation, temperature and humidity.

In addition, advances in the understanding of the ecology of disease organism, vectors, and their reservoirs and hosts have directed public health researchers to assess a greater range of environmental factors that promote disease prevalence, disease vector production, and the emergence and maintenance of disease foci.

Advances in computer processing, Geographic Information System (GIS), and Global Positioning System (GPS) technologies now make it easier to integrate ecological environmental and remotely sensed data for the purpose of developing predictive models that can be used in public health disease surveillance and control activities. These new capabilities will bring significant improvements in spectral spatial and temporal resolution, thereby making
it possible to address public health issues previously thought to be beyond the capabilities of remote sensing. The capabilities of remote sensing technology have not been completely disseminated to the Caribbean and Central American public health investigators and agencies that could be using them, therefore:

The goals of this public health endeavor should be to:

1. Generate a guide to satellite systems and data products that could be used for public health research, surveillance, control and modeling the distribution of human disease.

2. Develop and maintain a public health database on the Internet containing epidemiologic and environmental data, as well as individual sensor and data product characteristics.

The following criteria should apply:

1. Data products should be fairly straightforward to use, (i.e., not requiring a lot of complex pre-processing that requires non-public domain algorithms or calibration data from many other instruments).

2. Data products should be digital not photographic, to facilitate their use in geographic information systems and models, as well as integrated with other data.

Additional Information can be found at the following URL:

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- [http://www.pitt.edu/~super1/lecture/lec2771/index.htm](http://www.pitt.edu/~super1/lecture/lec2771/index.htm)
- [http://www.pitt.edu/~super1/lecture/lec6751/index.htm](http://www.pitt.edu/~super1/lecture/lec6751/index.htm)

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