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"Dengue, Aedes aegypti, and Hurricane Reconstruction - a slide presentation

Frank Cortez Flores

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My primary public health interest is the reemerging arboviral infections (e.g., dengue fever) that are increasing in incidence, expanding into new geographic areas, affecting new populations, and are threatening to increase in the near future, especially following natural disasters.

The goal of the dengue lecture series is to promote the recognition of dengue and dengue hemorrhagic fever and improve the understanding of factors involved in prevention, surveillance and control of the *Aedes aegypti* mosquito, the principal mosquito vector of dengue virus.
The paramount purpose of this lecture is to accelerate learning and development of an effective dengue prevention and control response plan for disaster mitigation. The theme of the lectures/presentations is awareness and learning.

The general nature of a dengue fever outbreak threat following a natural disaster and the resultant need for a well-designed preparation response and recovery create a demand for services and resources that cuts across an array of responsible and affected stakeholders.

**LEARNING OBJECTIVES**

Upon completion of these presentations, the learner should be able to:

* 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).

* Define how to strengthen the regional capacity for effective implementation of prevention and control strategies for disaster mitigation.

* 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.

* 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.
Dengue, an arboviral disease, is an arthropod-borne (e.g., mosquito-borne) viral infection of humans. Arboviruses consist of a group of animal viruses that are able to reproduce in an arthropod and can be transmitted to a vertebrate host.

Because of the degree of morbidity and mortality involved, dengue is considered the most important arboviral disease affecting humans.

The four dengue virus serotypes, designated DEN-1, DEN-2, DEN-3, and DEN-4, are ribonucleic acid (RNA) viruses belonging to the genus Flavivirus of the family Flaviridae.

Epidemics of dengue fever in urban communities are explosive and involve significant portions of the population. They often start during the hurricane/rainy season, when the vector mosquito, *Aedes aegypti*, is in abundance and thriving in urban areas.

*Aedes aegypti* is a domesticated mosquito with a short flight range, and urban spread of dengue is frequently house-to-house in a contiguous manner.

The mosquito breeds in tropical or sub-tropical climates in man-made water-holding receptacles in and around human habitation, or in tree holes or plants in close proximity to human dwellings.

These sturdy urban survivors are found in nearly every major city in the tropics, as well as in the sub-tropics, and they apparently prefer the blood of humans to that of other animals.
Dengue fever 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 presentation is to identify and address the dominating factors influencing the resurgence of dengue fever following a natural disaster such as a hurricane.

This lecture will 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 considered 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.
In the Americas, dengue fever intensified as a public health problem during the 1980s -- between 1980 and 1990 more than one million dengue cases were reported. Also, during those years, an increase in cases of the potentially fatal forms of dengue, dengue hemorrhagic fever and dengue shock syndrome, was observed in various countries of the Americas.

Prospects for reversing the recent trend of increased epidemic activity and geographic expansion of dengue are not promising. New dengue virus strains and serotypes will likely continue to be introduced into many areas where the population densities of Aedes aegypti are at high levels.

With no new mosquito control technology available, in recent years public health authorities have emphasized disease prevention and mosquito control through community efforts to reduce larval breeding sources.

Although this approach will probably be effective in the long run, it is unlikely to impact disease transmission in the near future. We must, therefore, develop improved, proactive, laboratory-based surveillance systems that can provide early warning of an impending dengue epidemic.

At the very least, surveillance results can alert the public to take action and physicians to diagnose and properly treat dengue/DHF cases.
The emergence of dengue/dengue hemorrhagic fever as a major public health problem has been most dramatic in the American region. In an effort to prevent urban yellow fever, which is also transmitted by *Aedes aegypti*, the Pan American Health Organization organized a campaign that eradicated *Aedes aegypti* from most Central and South American countries in the 1950s and 1960s. As a result, epidemic dengue occurred only sporadically in some Caribbean islands during this period.

The *Aedes aegypti* eradication program, which was officially discontinued in the United States in 1970, gradually eroded elsewhere, and this species began to re-infest countries from which it had been eradicated. In 1997, the geographic distribution of *Aedes aegypti* is wider than its distribution before the eradication program.

There is a small, but significant, risk for dengue outbreaks in the continental United States. Two competent mosquito vectors, *Aedes aegypti* and *Aedes albopictus*, are present and, under certain circumstances, each could transmit dengue viruses. This type of transmission has been detected three in the last 16 years in south Texas (1980, 1986, and 1995) and has been associated with dengue epidemics in northern Mexico.

Moreover, travelers returning from tropical areas where dengue viruses are endemic introduce numerous viruses annually. From 1977 to 1994, a total of 2,248 suspected cases of imported dengue were reported in the United States. Although some specimens collected were not adequate for laboratory diagnosis, 481 (21%) cases were confirmed as dengue.
The human population is growing exponentially, with virtually all of this growth occurring in urban zones. Compounding this problem, there is more population movement between urban centers within and among countries, more substandard housing, more artificial disposable containers and governmental services that are inadequate in these burgeoning urban centers.

As a result of these changes, the resurgence of *Aedes aegypti* (dengue fever) is presently much greater than it has been in the past. Worldwide, up to 100 million people annually are infected with dengue fever, mainly in tropical cities and urban areas, while 2.5 billion people are at risk of infection.

Human mobility and intervention also can be important for their role in introducing virus into susceptible populations. Increased air travel between urban centers of the tropics has been cited as a factor responsible for the increased frequency of dengue epidemics.

The geographic dissemination and endemic maintenance of dengue fever in the Americas and the Caribbean depends on the continued introduction of virus into susceptible human populations, spread within these populations, and low-level transmission during non-epidemic periods.
The reasons for the dramatic global emergence of dengue/dengue hemorrhagic fever as a major public health problem are complex and not well understood.

However, several important factors can be identified:

First, effective mosquito control is virtually nonexistent in most dengue-endemic countries. Considerable emphasis for the past 20 years has been placed on ultra-low-volume insecticide space sprays for adult mosquito control, a relatively ineffective approach for controlling *Aedes aegypti*.

Second, major global demographic changes have occurred, the most important of which have been uncontrolled urbanization and concurrent population growth. These demographic changes have resulted in substandard housing and inadequate water, sewer, and waste management systems, all of which increase *Aedes aegypti* population densities and facilitate transmission of *Aedes aegypti*-borne disease.

Third, increased travel by airplane provides the ideal mechanism for transporting dengue viruses between population centers of the tropics, resulting in a constant exchange of dengue viruses and other pathogens.
For the sake of brevity, reciting that the incidence of dengue fever and dengue hemorrhagic fever, an acute febrile illness transmitted by the *Aedes aegypti* mosquito, is on the rise can succinctly summarize this graph. Hundreds of thousands of dengue cases are reported worldwide each year.

Given the difficulty in obtaining full reporting, the actual number of human infections is probably much higher than the number reported. In the recent past, dengue transmission has increased in most countries of the Americas and epidemics are occurring at more frequent intervals.

Along with the increased incidence of dengue fever has been the emergence of dengue hemorrhagic fever, with a major epidemic in Cuba (1981) and a smaller epidemic in Mexico (1984). Moreover, there has been an increased occurrence of dengue hemorrhagic fever cases throughout this region.

Many more cases probably go unreported each year because surveillance is passive and relies on physicians to recognize the disease, inquire about the patient's travel history, obtain proper diagnostic samples, and report the case.

These data suggest that the Americas, following a hurricane, are at risk for increased dengue transmission and sporadic outbreaks.
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.
Hurricane Mitch and Hurricane Georges were among the most severe and powerful storms ever to hit Central America and the Caribbean in the history of the hemisphere.

Hurricane Mitch, carrying 180-mph winds at its height on October 26 and 27, 1998, produced massive flooding and destruction, engulfing entire villages and destroying homes, crops and infrastructure. The face of these countries was permanently changed by the devastation.

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.
Hurricane Mitch was the most destructive storm in the Atlantic Basin in the past 200 years.

It reached sustained wind speeds of 180 mph while moving into the western Caribbean but the main destruction resulted from intense rainfall.

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.
Changes in global and local temperatures and rainfall could expand the geographical distribution of the *Aedes aegypti* mosquito, affect its behavior, and increase the rate of development, thus increasing the risk of transmission of dengue.

Additionally, extreme weather conditions, such as heat and heavy flooding, can produce the right environmental conditions for an outbreak. Major upsurges of dengue, in some nations such as Colombia in 1995, follow periods of heavy rains.

It has been noted in the literature that in addition to climatic and environmental disruptions and changes, the movement of people, arthropod-vector, plants, and other particulars can increase exposure to dengue.
The 1998 hurricane season was one of the most devastating with major hurricanes Georges and Mitch causing widespread damage and destruction in Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Dominican Republic, Haiti, and the Eastern Caribbean.

Forecasts for the 1999 Hurricane season indicate the potential for the development of several major storm systems, which may result in a humanitarian disaster of equal magnitude.

One of the most important activities of the years following the 1998 hurricane season was incorporating the lessons learned from Hurricanes Mitch and George into regional planning not only for reconstruction but to ensure that the region is better protected and less vulnerable during future hurricane seasons.
There should be regional support for disease surveillance and early warning system to ensure effective response to natural disasters, including strengthening health surveillance and readiness systems.

Moreover, reconstruction programs should look at:

* Natural hazard vulnerability and risk assessments;

* Risk management planning;

* Land use and river basin development planning;

* Improved construction technologies for disaster resistant housing;

* Critical watershed protection;

* Flood control;

* Landslide stabilization;

* Improving resiliency of transport systems to natural disasters;

* Public awareness campaigns; and

* Development of capacity (at regional, national, and local levels) for disaster mitigation, preparedness and response.
Estimates of the human and economic toll exacted by Hurricane Mitch are that over three-fourths of Honduras’ total population were affected by the hurricane, with more than 5,000 dead, over 12,000 injured, and over 8,000 missing.

Projections of total economic losses range beyond $4 billion and include some $1 billion in agricultural losses. In response to Mitch, the U.S. mounted one of the largest international emergency relief responses to a natural disaster in U.S. history.

The strategy response to the changed development context after a natural disaster (e.g., Hurricane Mitch) should address the most critical hurricane reconstruction needs:

* Public Health
* Education · Shelter
* Environmental Management
* Disaster Mitigation
* Economic Reactivation.
The human and economic toll exacted by Hurricane Mitch was staggering.

More than 9,000 people were killed, 13,000 injured, and 3 million displaced.

In one single, tragic mudslide in Posoltega, Nicaragua, 2,000 people perished.

Hundreds of bridges, thousands of schools, clinics and kilometers of roadway were destroyed or damaged.

There were also severe losses to rice, corn, beans, coffee and banana crops, the basic economic main stay of thousands of poor farmers and consumers.

Direct and indirect damages from the storm were estimated at more than $8.5 billion in Honduras, Nicaragua, Guatemala and El Salvador, with $3.4 billion in Honduras alone.
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 increased-sediment 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.

In The Caribbean, 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.
The dirty standing water that became commonplace in the Hurricane Mitch-ravaged zones placed the rural population in peril of mosquito-transmitted diseases.

Mosquito nets that are impregnated with Permethrine, an approved chemical compound that both repels and kills insects/mosquitoes, should be distributed to combat dengue.

This effort would be especially beneficial to small children who were more vulnerable to serious illnesses, such as dengue fever/dengue hemorrhagic fever.

Infectious diseases account for the larger part of all deaths in the tropical areas of the world and disease, like poverty, is not distributed uniformly among people and countries.

Nearly all of these deaths occur in children under the age of five. Many of these infectious diseases that profoundly impact the health of people living in the tropics are frequently referred to as arboviral diseases.

Arboviruses are enveloped, RNA-containing viruses that encompass, among others, the Flaviviruses (family Flaviviridae, genus Flavivirus) that is pathogenic in humans and includes dengue.
Hurricane Mitch was the most destructive storm in the Atlantic Basin in the past 200 years. It reached sustained wind speeds of 180 mph while moving into the western Caribbean but the main destruction resulted from intense rainfall.

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.
The epidemiologist’s traditional role to study infectious disease outbreaks, control their spread, and devise appropriate prevention will contribute to the reconstruction effort through a variety of activities involving the improved capacity of institutions to respond to infectious and preventable disease.

**Vital program elements should include:**

* Rehabilitation of disease surveillance and active use of information for public health decisions;

* Increased availability of trained epidemiologists in the region and the training of other levels of health workers by these epidemiologists;

* Rehabilitation of infectious disease and environmental health laboratory capacity;

* Institutionalization of capacity of ministries of Health to design and implement community based prevention and control of disease programs; and

* Support for natural hazard vulnerability assessments, disaster risk management planning, information collection and management systems, and development of disaster early warning systems.
Advances in computer processing, Geographic Information System (GIS), Remote Sensing (RS) 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.
Remote Sensing (RS) and Geographic Information Systems (GIS) are map-based tools that can be used to study the distribution, dynamics, and environmental correlates of diseases.

RS is gathering digital images of the earth's surface from airborne or satellite platforms and transforming them into maps.

GIS is a data management system that organizes and displays digital map data from RS or other sources and facilitates the analysis of relationships between mapped features.

Statistical relationships often exist between mapped features and diseases in natural host or human populations.

Examples include malaria and dengue fever in The Caribbean and Central America.

RS and GIS may also permit assessment of human risk from many other pathogens.

RS and GIS are most useful if disease dynamics and distributions are clearly related to mapped environmental variables.

For example, if a disease is associated with certain vegetation types or physical characteristics (elevation, average precipitation), RS and GIS could identify regions where risk is relatively high.
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.

However, 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.

The goals of this public health endeavor should be to:
* 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.

* 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.
Hurricane Mitch and Hurricane Georges were among the most severe and powerful storms ever to hit Central America and the Caribbean in the history of the hemisphere.

Hurricane Mitch, carrying 180-mph winds at its height on October 26 and 27, 1998, produced massive flooding and destruction, engulfing entire villages and destroying homes, crops and infrastructure. The face of these countries was permanently changed by the devastation.

Moreover, in most countries of this region the public health infrastructure has deteriorated. Limited financial and human resources and competing priorities have resulted in a "crisis mentality" with emphasis on implementing so-called emergency control methods in response to epidemics rather than on developing programs to prevent epidemic transmission.

This approach has been particularly detrimental to dengue control because, in most countries, surveillance is (just as in the U.S.) very inadequate; the system to detect increased transmission normally relies on reports by local physicians who often do not consider dengue in their differential diagnoses.

As a result, an epidemic has often reached or passed transmission before it is detected.
The human and economic toll exacted by Mitch was staggering.

More than 9,000 people were killed, 13,000 injured, and 3 million displaced.

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Direct and indirect damages from the storm were estimated at more than $8.5 billion in Honduras, Nicaragua, Guatemala and El Salvador, with $3.4 billion in Honduras alone.

A region-wide support, for risk management planning, public awareness campaigns, and capacity building of regional, national and community disaster management organizations for mitigation and preparedness, can help to strengthen transnational linkages.
Hurricane Mitch claimed the lives of more than 2,000 people in the municipality of Posoltega, when torrential rains triggered a mudslide down the slopes of the Casita volcano, burying two entire villages.

Debris from the mudslide choked riverbeds and changed watercourses.

In identifying sites in the Posoltega watershed that posed a high risk of flooding, the most serious threat was the likelihood that, because of the silting up of the channel, the Posoltega River would overflow and inundate the town of Posoltega itself as soon as the rains returned.
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.
The intent of an effective surveillance system is to provide early and precise information to public health officials on four aspects of increased dengue activity: Time; Location; Virus Serotype; and Disease Severity.

The purpose would be to reduce transmission, thereby reducing the probability of dengue hemorrhagic fever/dengue shock syndrome. It should, therefore, be a proactive surveillance system that will allow for early detection of dengue cases and thus will improve the capacity of public health officials to prevent and control the spread of dengue. The most significant characteristic of this type of surveillance is its predictive capability.

Analysis of trends of reported cases, the establishment of sentinel clinics, the confirmation of dengue cases by the laboratory, and the rapid identification of the serotypes involved in transmission, provide the necessary information to predict dengue transmission and guide implementation of control measures well in advance of peak transmission. Proactive clinical surveillance must be linked to entomologic surveillance, in order to identify dengue transmission in time and place.

This lecture/presentation supports 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. There should be collaboration in contingency planning, pre-positioning of relief commodities, hurricane pre-deployment rotations, and training in disaster response, mitigation and preparedness. 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.