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Hurricane Preparedness, Response and Recovery Guide for the United States
Virgin Islands

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Abstract

The United States Virgin Islands (USVI) are composed of four small islands located at the Eastern end of the Great Antilles in the northern Caribbean Sea. The USVI are located in Hurricane Alley which makes the area highly susceptible to many natural disasters, especially hurricanes. In the past 25 years, 11 major hurricanes have caused substantial damage to the USVI. Hurricanes are massive storm systems that form over ocean water and often move toward land. Hurricane season starts June 1st and ends November 30th every year. Most major hurricanes occur between August and September. Depending on wind speed, hurricanes are classified according to the Saffir-Simpson scale (Categories 1 through 5): category one is the least destructive and category five is the most destructive. Hurricane effects vary depending on the category and can be considerable. Some of the threats from hurricanes include high winds, heavy rainfall, storm surge, coastal and inland flooding, rip currents, flood damage, flying debris, damage by fallen trees, the collapse of buildings, and tornadoes. During an active hurricane, the greatest threat to life and property is from the storm surge. Storm surge can severely erode beaches, coastal highways and damage property along the coastline.

Hurricanes have become more frequent and intense over the past few years. On September 6, 2017, Hurricanes Irma devastated St. Thomas and St. John with sustained winds of 106 mph for 14 days(1). Later, on September 20th, Hurricane Maria passed through the western end of St. Croix with sustained winds of 178 mph and hit the U.S. Virgin Islands (2).

Hurricanes are the most costly natural disaster. The year 2017 had a historically high cost of 306 billion USD in hurricane disaster damage, relief and recovery that impacted the United States economy (3). It is critical that all affected regions have a preparedness, response and recovery plan in action. Although preparedness is key in reducing damage caused by hurricanes, immediate response to hurricanes can save lives and minimize disaster damage. Lastly, Collaboration among governmental, non-governmental, local community, volunteers and disaster relief workers are essential.

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List of Abbreviations

Table 1: Abbreviations

	Abbreviation	Meaning
1	CDC	Center for Diseases Control and Prevention
2	CERT	Community Emergency Response Team
3	CO	Carbon Monoxide
4	EPA	Environmental Protection Agency
5	FEMA	Federal Emergency Management Agency
6	GPS	Global Positioning System
7	MMWR	Morbidity and Mortality Weekly Report
8	NHC	National Hurricane Center
9	NOAA	National Oceanic and Atmospheric Administration
10	PTSD	Post-traumatic Depression Stress Disorder
11	SUV	Spontaneous Unaffiliated Volunteers
12	USDA	United States Food and Drug Administration
13	USVI	United States of Virgin Islands
14	VITEMA	Virgin Islands Territorial Emergency Management Agency

Introduction

Tropical Cyclones causes significant loss of life and damage to property and the environment. Tropical Cyclones are rapidly rotating storm systems characterized by a low-pressure center and low-level atmospheric circulation having a speed of at least 74 mph,

producing heavy rain and thunderstorms. They are known by different names depending on the part of the world they form. If they form in the Atlantic Ocean or the northeastern Pacific Ocean, they are called hurricanes. Hurricanes are the most costly natural disaster known to man. The congressional budget office estimates that every year the United States spends \$28 billion on hurricane damage (4). In 2017, “Hurricane Harvey, Irma, Maria caused a combined \$265 billion in damage and resulted in widespread displacement of survivors” (5). The United States (including the United States Virgin Islands and Puerto Rico) is no stranger to the phenomenon as the frequency and intensity of these destructive storms has increased over the past few decades since the ‘Industrial Revolution.’

The year 2017 was especially destructive for many of the Caribbean Islands, with the United States Virgin Islands (USVI) hit by two category five hurricanes. Hurricanes Irma and Maria brought about unprecedented damage and destruction to the islands and exposed the shortcomings and loopholes in the emergency response systems for the island. The goal of this project was to investigate the strengths and weaknesses of the emergency preparedness and response procedures of the USVI. In addition, this project developed a deliverable emergency preparedness guide for the USVI that includes personal protection, contact information for emergency services, emergency shelter information and steps to follow for storm recovery assistance and hazard mitigation

Methodology

The methodology for the compilation of the special project included obtaining data from preexisting sources in print and electronic formats and also through collaboration with the local, regional, and national government entities. Research for this project also consisted of in-person

and phone conversations with public health officials and the local community that was involved in the emergency preparedness and response plan during Hurricane Irma and Hurricane Maria in the USVI.

The initial approach involved communicating with Hurricane Maria survivors in St Croix to elicit their experiences. This special project did not require IRB approval, as it was used to gather experiences of hurricane survivors using informal interviews. All interviewees were over the age of 18.

Some of the general questions included in the interview were the following: Did they feel they were prepared for the hurricane and would they do anything differently in the future? They were also asked if they decided to evacuate or proceed to a designated shelter or sheltered in place. Based on their responses, they were asked how they arrived at this decision and if they would do it differently next time. After the informal interviews with the local community, a snowball sampling method was used to interview other key informants. My second approach focused on making contact with workers from the Federal Emergency Response and Management Agency (FEMA). An official request was submitted to interview any officials who could further contribute to the research. Thereafter, the hazard mitigation advisor for the Virgin Island Territorial Emergency Management Agency (VITEMA) was interviewed. The interview focused on the standard procedure for hurricane preparedness plan, the challenges as well as the future mitigation and resilience plan. After addressing these questions, he further suggested contacting the government of the USVI Department of Property and Procurement for more information on transportation and resource management. The Department of Property and

Procurement provided an informational booklet for their disaster/emergency operation plan that explained the emergency support functions and departmental responsibilities.

To complete the literature review, information was collated from various websites including the National Hurricane Center (NHC), Federal Emergency Management Agency (FEMA), Center for Disease Control and Prevention (CDC), National Oceanic and Atmospheric Administration (NOAA), Virgin Islands Territorial Emergency Management Agency VITEMA. Additionally, peer-reviewed articles from the PubMed database were reviewed.

Table 2: Literature Search Strategy

Databases searched	PubMed
Website searched	CDC, FEMA, VITEMA, NHC, and NOAA
Keywords and phrases searched	<ul style="list-style-type: none"> • Hurricanes • Hurricane Maria • Hurricane Irma • Hurricane preparedness • Hurricane vulnerability • Economic impact of hurricanes • Community emergency response • Governmental and non-governmental hurricane response • Hurricane history in the USVI • Overview of USVI (Geography) • Hurricane response and recovery • Community involvement gap during a disaster. • Hurricane mitigation and resilience • Lesson learned from hurricane Irma and Maria • Hurricane Impact on the environment (USVI) • Hurricane Katrina’s Environmental Impact of in Louisiana • Hurricane Related Infectious diseases in the USVI • Hurricane and Vector borne diseases • The aftermath impact of hurricane on mental health
Years covered by search	1989-2019 (30 years)
Publication Language	English
Geography	United States Virgin Islands, Louisiana, Florida, and Puerto Rico

Literature Review

Brief review of the United States Virgin Islands.

The United States Virgin Islands (USVI) are part of the United States territory located at the Eastern end of the Great Antilles in the northern Caribbean Sea, neighboring the British Virgin Islands. The territory is made up of four islands, St. Croix, St. Thomas, Water Island and St. John. Geographically, the U.S. Virgin Islands are an extension of the fault-block mountain ranges that are part of the Great Antilles.

St. Croix

St. Croix, also known as Twin city, is the largest of the United States Virgin Islands. St. Croix is located at 17°45'N 64°45'W, the easternmost point in the United States of America. St. Croix's temperature variance(6) is extremely consistent throughout the year. The island has a surface area of 83 sq. miles. The east end is a dry desert area with a large amount of cactus, while lush vegetation and palm trees are on the west end (6). Within a small geographic area, the island has several ecosystems. Severe drought has always been a challenge, especially given the lack of fresh groundwater and limited streams and rivers on the island. St. Croix is the home of Cruzian Rum and Captain Morgan Rum distilleries; however, similar to other Caribbean islands, tourism is the main revenue generator for the island. Forty-seven percent of USVI population lives in St. Croix (7).

St. Thomas

Saint Thomas is the second largest of the USVI with 31 sq. miles in size. With a tropical wet and dry climate, Charlotte Amalie is the territory's capital located on the southern portion of the main island. The geographical attributes of Saint Thomas are comprised of ridged hills running east and west with the highest elevation on the island being Crown Mountain (1,556 ft). Saint Thomas is surrounded by 17 islands, cays and innumerable rocks. It is famous for its white-

sand beaches in the West Indies: in particular Magen's bay is famous for 3500 sq. ft. of white sandy beach (8).

St. John

Saint John, is 9 square miles in size and It is approximately 4 miles to the east of Saint Thomas with a total population of 4,197 people based on the 2000 census. Saint John is accessible only by boat and the ferry service runs on an hourly schedule from Saint Thomas and Saint John. Nearly sixty-percent of the island consists of the Virgin Islands National Park. Known for its attractive beaches and natural beauty, Saint John has one of the top ten beaches in the world, and several resorts to cater to honeymoon getaways and the exotic tourist population. This makes it the wealthiest of the U.S. Virgin Islands. Some of the upscale tourist establishments in Saint John are the Rotunda Villa at Peter Bay and the Seacove Villa. The geographical attributes of Saint John are comprised of a mixture of hills, valleys and very little land conducive to agriculture and tillable land. Two of the highest elevations on the island are Bordeaux Mountain and Camelberg Peak. The coastline of the island is lined with forests and sheltered cays (9).

Water Island

Water Island is located 0.5 miles to the south of Saint Thomas. In 1996 Water Island officially became part of the U.S. Virgin Islands. According to the 2010 census, Water Island is home to 182 residents. Given the size and the population, Water Island does not have offer its public transportation, a service station, tourist lodging, or a central town. Most tourists depend on Saint Thomas for these essentials. Ferry services are provided between St. Thomas and Water Island (9).

Hurricane History in the United States of Virgin Islands.

The United States Virgin Islands are not new to hurricanes. On average, a hurricane passes the Virgin Islands every three years, and hurricanes hit the islands directly every eight years. Hurricanes are the largest natural hazard threat to the Caribbean islands.

The Virgin Islands are located in Hurricane Alley, making them especially vulnerable to these storms. Hurricane Alley is the warm area in the Atlantic Ocean that extends from the northwestern coast of Africa to the east coast of Central America and the Gulf coast of the United States. Hurricane Hugo (1989), Hurricane Marilyn (1995), Hurricane Bertha (1996), Hurricane Georges (1998), Hurricane Lenny (1999), Hurricane Omar (2008) and recently Hurricane Irma and Hurricane Maria (2017) are hurricanes that have caused substantial damage to the United States Virgin Islands over the past 25 years.

Hurricane Hugo (1989)

Hurricane Hugo struck the island of Saint Croix as a category four hurricane on September 18, 1989. Hurricane Hugo produced 140 mph of sustained winds with 2-3 ft. storm surge and ocean waves that were 20-23 ft. tall (10). The island's infrastructure such as banks, hospitals, power lines, and telephone lines were destroyed. After the disaster, 60-90 % of the buildings in St. Croix were damaged. Saint Croix was non-functional and did not have power for 6 months. President George H.W. Bush sent 1100 armed military police and 170 federal law enforcement officers that were members of the XVIII Airborne Contingency Corps to Saint Croix Island as part of Operation Hawkeye for two months. In combination with Puerto Rico, damage estimates were 1 billion dollars (9).

Hurricane Marilyn (1995)

Seven years after Hurricane Hugo, on September 15, 1995, Hurricane Marilyn had a wind speed of 100 mph and 11.67 inches of rain recorded in St. Croix. In Saint Thomas, there was a total of 9.96 inches of rainfall, and the storm surge was 6.6 ft. As a result of the storm, there were 13 fatalities, 80% of the homes were destroyed and 10,000 St. Thomas residents were left homeless. In total, Hurricane Marilyn resulted in \$1.5 billion of damage to the islands (11).

Hurricane Bertha (1996)

Hurricane Bertha walloped the USVI with heavy rain and wind that gusted to 103 mph on the July 9, 1996. Hurricane Berta damaged 1,415 homes with a total estimated cost of \$7.5 million (9).

Hurricane Erika (1997)

On the island of Saint Thomas, Hurricane Erika generated winds of 37 mph on September 8th, 1997. Wind gusts were recorded at 47 mph, the rainfall in Saint Thomas totaled 3.28 inches, and rainfall in Saint John totaled 1.32 inches. There were power interruptions and localized street flooding as a result of the winds and rain. On the island of Saint Croix, there were recorded winds of 25 mph. Maximum wind gusts were recorded at 29 mph. The storm also caused a few downed power lines in the town of Christiansted, but overall damage was minor (9).

Hurricane Georges (1998)

The total rainfall produced by Hurricane George was 6.79 inches in Saint Croix and 5.26 inches in St. Thomas (12). The major damage of the storm was to livestock and agriculture. In total, 20 homes were destroyed and an additional 50 homes sustained damage. As a result, some residents on Saint Croix were left without power due to downed power lines. The estimated loss from Hurricane George 2 million dollars (9).

Hurricane Lenny (1999)

The island of Saint Croix recorded rainfall accumulation of 8 inches on its southwest side. Hurricane Lenny generated winds up to 155 mph. A 15-foot storm surge was also generated. The agricultural sector was particularly affected by the strong winds and rainfall of Hurricane Lenny. There were no deaths resulting from the storm (9).

Hurricane Omar (2008)

Hurricane Omar generated more than 7 inches of rainfall on the island of Saint Croix. The sustained winds of the storm were recorded at 53 mph on the island of Saint Croix. Maximum wind gusts were 72 mph. Ocean waves were as high as 15 ft. As a result, 47 boats were sunk by Omar. A majority of Saint Croix's 55,000 residents were left without electrical power. Damage estimates on the island of Saint Croix were 700,000 dollars. An additional \$1 million was incurred in clean-up costs. The island of Saint Thomas was also left without power. Damage estimates on the island of Saint Thomas was \$5.3 million (9).

Hurricane Earl (2010)

Hurricane Earl generated high winds and maximum rainfall totals of 3.02 inches. The island of Saint Thomas suffered damage to roadways and electrical power lines. Though structural damage was minimal, many residents were left without electrical power for up to an entire week. Damage totals were estimated to be around \$2.5 million dollars. The business sector lost an estimated \$10.7 million in revenue due to tourist cancellation of travel plans to the Virgin Islands. In September 2010, The President Barack Obama approved a request for a major disaster declaration as proposed by the territory's governor (9).

Hurricane Irma

Hurricane Irma originated from a tropical wave that departed the west coast of Africa on 27th of August 2017 (13). Hurricane Irma was one of the most powerful Atlantic storms to be recorded in the past century. Hurricane Irma tore its way through the U.S. Virgin Islands as a Category 5 storm on Sept. 6, as a mixture of deadly winds and rising tides. It is estimated that the island of St. John had 80 percent of its structures extensively damaged (14). Many residents in the U.S. Virgin Islands were evacuated to Puerto Rico on cruise ships as the scope of damage ensured that it would be weeks or months until full access to drinking water and electricity was reinstated. Most residents from St. John were asked to evacuate; while those from St. Thomas and St. Croix were additionally offered an opportunity to evacuate .

Hurricane Maria

On the 20th of September, just two weeks after Hurricane Irma had ravaged the islands; a second hurricane, Hurricane Maria, struck the USVI as a category 5 and the island of Puerto Rico as a category 4. This only made the situation on the ground worse and severely damaged power distribution, water and wastewater management and other physical infrastructure on the island. The highest winds officially observed on the island were at Cotton Valley RAWS, located on the east end of St. Croix an average wind speed of 99 mph (9).

Hurricanes

Hurricanes are massive storm systems that form over ocean water and often move toward land. Warm ocean water (more than 80 F) gives energy to the hurricane, which leads to more evaporation making humid air and clouds (15). Different current winds come together and

force the air upward. Depending on wind speed, hurricanes are classified into 5 different categories based upon the Saffir-Simpson scale (below).

Category	Wind (MPH)	Potential Damage
5	>156	Catastrophic
4	131-155	Extreme
3	111-130	Extensive
2	96-110	Moderate
1	74-95	Minimal

Table 3 Saffir-Simpson Hurricane Scale

Hurricane season starts June 1st and ends November 30th. Most major hurricanes occur between August and September (16).

Hurricane effects

Hurricane effects vary depending on the categories and can be considerable. Some of the threats from hurricanes include high winds, heavy rainfall, storm surge, coastal and inland flooding, rip currents, flood damage, flying debris, damage by fallen trees, the collapse of buildings, and tornadoes. Heavy winds and storm surge are the two main effects of hurricanes. Hurricanes cause injuries and death primarily from drowning, wind, and wind-borne debris.

Storm Surge

During an active hurricane, the greatest threat to life and property is from the storm surge. A storm surge is an atypical increase in water caused by a storm, in addition to the expected astronomical tides. Storm surge can severely erode beaches, coastal highways and damage properties along the coastline. The storm surge generated during Hurricane Marilyn

(1995) in St. Thomas was 6.6 ft. and resulted in 80% of homes and business on the island being destroyed. This resulted in over 10,000 of the residents becoming homeless (9).

High Winds

Hurricane categories are determined based on wind speed. Hurricane winds impact homes, building, boats, and trees. Wind can damage structures, bridges, and roads. When differential pressures are applied to buildings, the pressure will drive the walls to collapse and the roofs to fly off. High wind is also associated with moving debris from one area to another and potentially destroying homes and buildings. There is also a high risk of death and injury to people due to falling debris and flying objects.

Frequency and Intensity of hurricanes in the US. Virgin Islands

Hurricanes are becoming more frequent and intense. On September 6, 2017, Hurricane Irma devastated St. Thomas and St. John with sustained winds of 106 mph and 14 days (2). Later, on September 20th, Hurricane Maria Passed through the western end of St. Croix with sustained winds of 178 mph and hit the U.S. Virgin Islands. According to the National Oceanic and Atmospheric Administration (NOAA), Hurricane Irma and Hurricane Maria are in the top 5 coastline hurricanes on record.

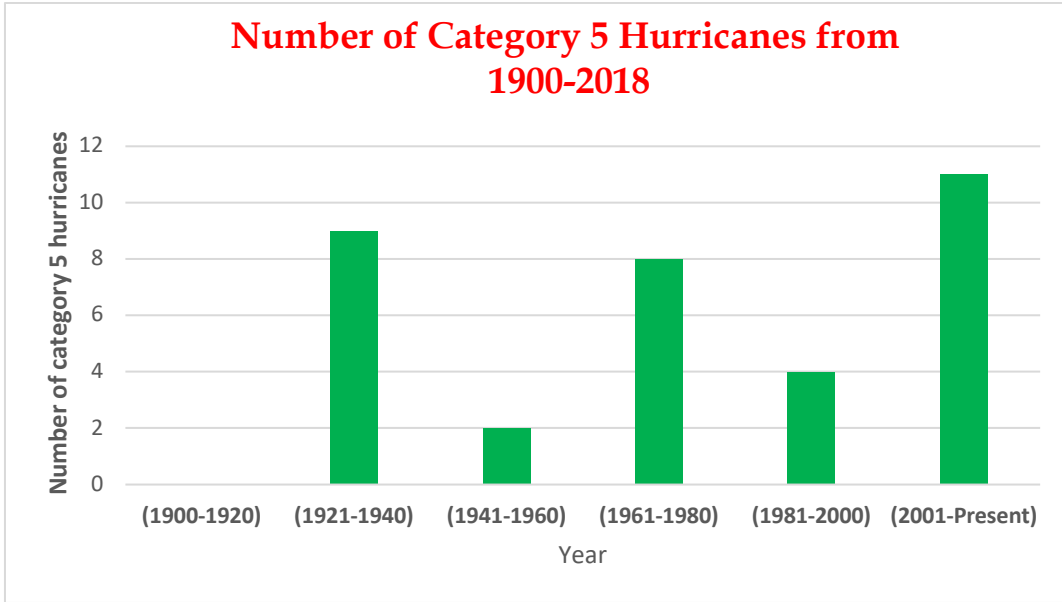


Figure 1 Number of Category 5 Hurricane from (1900-2018)



Figure 2 Data: National Hurricane Center, Graphic: Michael Lowry (September 19th, 2017)

Figure 1 and figure 2 shows number of category 5 Atlantic hurricanes in the 25 years. According to the data, 33% of all category five hurricanes on record occurred in the past 12 years (17). As the sea surface temperature increases, it is expected that there will be an increase in the number and intensity of hurricanes.

Economic Impacts of Hurricanes

Hurricanes are the most costly natural disaster. As the population increases, more people will start moving to the coastal areas. According to a study conducted by the National Oceanic and Atmospheric Administration in 2010, 39% of the United States population lived directly on a shoreline. This study also estimates that the population will increase by 8% (notably this study excluded Alaska, Hawaii and U.S. Territories). Of note, coastal counties are six times as densely populated relative to the inland counties. According to the 2012 United States census bureau data, the densely populated areas in the United States are located along the east coast. Along the east coast, the top 3 costliest hurricanes occurred since 2005; the most expensive being Hurricane Katrina 2005 (Louisiana, Alabama, and Mississippi) tied with Hurricane Harvey 2017 (Texas and Louisiana) each costing over USD 125,000 billion and Hurricane Maria 2017 (Puerto Rico and United States Virgin Islands) following with USD 90 billion in damage (18).

Economic Impact of Hurricanes on the United States Virgin Islands

Prior to the two devastating hurricanes, Hurricane Irma and Maria hit the U.S. Virgin Islands, tourism was the predominant revenue source for the USVI with about 1.2 million cruise passengers and about 400,000 airplane passengers visiting arrived each year (19). HOVENSA oil refinery in St. Croix was the USVI's largest employer, with 1,200 workers and 1000 contractors prior to its sudden shut down in 2012 (20). Hurricane Irma caused significant damage to the

energy, water, and communication infrastructure on the St. Thomas, St. John and Water Islands. Hurricane Maria took place two weeks after Hurricane Irma that blacked out St. Croix and caused more flooding on St. Thomas.

According to the Congressional Research Service report, the tourism industry was severely disrupted after Hurricane Irma and Maria, and as a result, the public revenue decreased by 50% (20). The total unemployment rate on the islands increased by 12% between August 2017 and November 2017. In November 2017, the USVI government estimated that uninsured damage from the hurricanes would exceed \$7.5 billion (20). It is estimated that 18,500 homes and business were damaged, and the fishing industry also lost \$3.2 million in revenue and 46 jobs. Three months after Hurricane Irma and Maria, hotel reservations decreased by 78% compared to the previous year. In June 2017, major airlines also reported a 43% drop in bookings (21).

History of Hurricane preparedness

In the United States, President Jimmy Carter signed an executive order on April 1st, 1979, to create a federal emergency management agency (FEMA). FEMA's mission is to lead the United States to prepare for, prevent, respond, and recover from natural and human-made disasters. In addition to helping the community prepare for emergencies, FEMA employs over 14,000 employees across the country (23). Before the establishment of FEMA, different governmental agencies were responsible for disaster response. In the early 1930s, the reconstruction finance corporation was responsible for disseminating loans and finance for reconstruction infrastructure projects after a disaster (24). Later the Bureau of public roads was responsible for rebuilding roads and bridges after natural disasters. In 1973, the flood disaster

protection act made it mandatory to purchase flood insurance for properties located on a flood plain (23). In the following year, 1974, President Nixon passed the Disaster Relief Act that allowed the president to declare a state of emergency(23).

Hurricane preparedness/Emergency Preparedness

Disaster management is designed to reduce, prevent potential hazard losses, provide prompt and appropriate support for disaster victims, and ensure a speedy and effective recover.

Disaster response is composed of four major phases.

- Mitigation - Minimizing the effects of disaster.
- Preparedness - Planning how to respond.
- Response - Efforts to minimize the hazards created by a disaster.
- Recovery - Returning the community to normal. (Often times resilience is included in the recovery phase.



Figure 3 Disaster Management cycle

Emergency preparedness is both an active area of research and an applied field at the governmental and community levels. The process of emergency preparedness starts by

assessing the type of threat (i.e. natural or humanmade). Once the risk is recognized, the next step is to identify the level of preparedness needed, who the vulnerable population is, and determine whether a local preparedness plan already exists to use as a base structure. Emergency preparedness is a collaborative effort that includes volunteers, community participants, government and non-governmental agencies. FEMA has four essential community and family preparedness plans for any disaster .

1. The first step is identifying the nature of an emergency that is most likely to occur and reach out to the local emergency preparedness or Red Cross and acquire more information and guidance on how to better prepare for it.

2. If the disaster is seasonal, such as with hurricanes, the recommendation is to draft a family disaster plan before the event has occurred. Then, community members should hold family meetings to discuss the plan for an upcoming disaster.

3. Assign each member with a task to do and keep them accountable.

4. Practice adherence to the plan. Ensure that the plan is achievable and easy to understand and execute.

The hurricane preparedness plan specifically for United States Virgin Islands is attached as a supplemental document.

Vulnerability

Vulnerability and disaster preparedness always go hand in hand. It is important to identify and understand vulnerable populations when planning for an emergency to reduce the damage or loss. According to the United Nations Office for Disaster Risk Reduction, vulnerability can be categorized in to 4 different categories, physical vulnerability, social

vulnerability, economic vulnerability and environmental vulnerability(25) . Vulnerability is a weakness that allows exposure to various risks and social harm. In a community, there are various groups of people susceptible to such injuries. Physical vulnerability is one type of vulnerability (26). After Hurricane Katrina and Hurricane Rita in 2005, geographical or physical vulnerability has gained some attention in the media and the federal government. Physical vulnerability associated with hurricanes occurs to the southeastern coast of the United States and the Caribbean islands. Two years after Hurricane Irma, Harvey and Maria; Puerto Rico, Texas, and the United States Virgin Islands are still in the recovery stage.

The Center for Disease control describes social vulnerability as how resilient a community is when confronted by external stressors on human health (27). Prior to the 2017 hurricanes, 61% of the United States Virgin Islands population was extremely dependent on government services; the low-income population being highly reliant on the government support by the elderly, juvenile delinquents, young children, mental and physical disability (28). During the hurricane, the population that was dependent on government services was very vulnerable.

During Hurricane Maria, although the hurricane affected the entire island of Puerto Rico, the poorer and more remote communities suffered the most. The vulnerable population had less access to health care, more fragile homes and no electricity or generators for the already replenished health care services.

[Hurricane response and recovery](#)

The 2017 hurricane season was one of the most active seasons with three highly destructive storms in history. Although preparedness is key on reducing the damage from hurricanes, response and recovery plays an important role minimizing the effect.

After a disaster, it is important that there is a response and recovery plan in action. Immediate response to hurricanes can save lives and reduce disaster damage. Disaster response is the second phase in a disaster management cycle. The initial step for hurricane response on the federal/state and local government level is warning/evacuation, later followed by search and rescue. The first level of disaster response on an individual level is risk assessment and identifying the potential damage. As part of the assessment, workers and local community should assess for the levels of Carbon Monoxide (CO) in the air (29). As a result of power outages during and after hurricane people use generators as a source of power, which produce CO. According to CDC, one generator produces as much CO as hundreds of cars. To avoid CO poisoning, individuals should never run a generator, pressure washer, or any gasoline-powered engine inside a basement, garage, or other enclosed structure, even if the doors or windows are open. Leaving the motor running for a vehicle parked in an enclosed or partially enclosed space, such as a garage, can increase chance of CO poisoning.

Hurricanes create an unsafe working environment for emergency responders and other disaster relief workers. Safety is a major concern during a response. While cleaning and removing debris, wearing personal protective equipment (PPE) is important to avoid accidents. When using chemicals for cleaning, it is very important to read the labels thoroughly. As an example, one should never mix bleach and ammonia.

Mold is also a major issue after hurricanes. It is important to wear N-95 respirators when cleaning mold. Individuals with pre-existing respiratory conditions such as asthma, pregnant women and immunocompromised are at high risk of mold infections during hurricane clean up (30).

Governmental vs non-governmental response

During a natural disaster, it is essential that governmental, private sector humanitarian organizations and non-governmental agencies collaborate in the response effort.

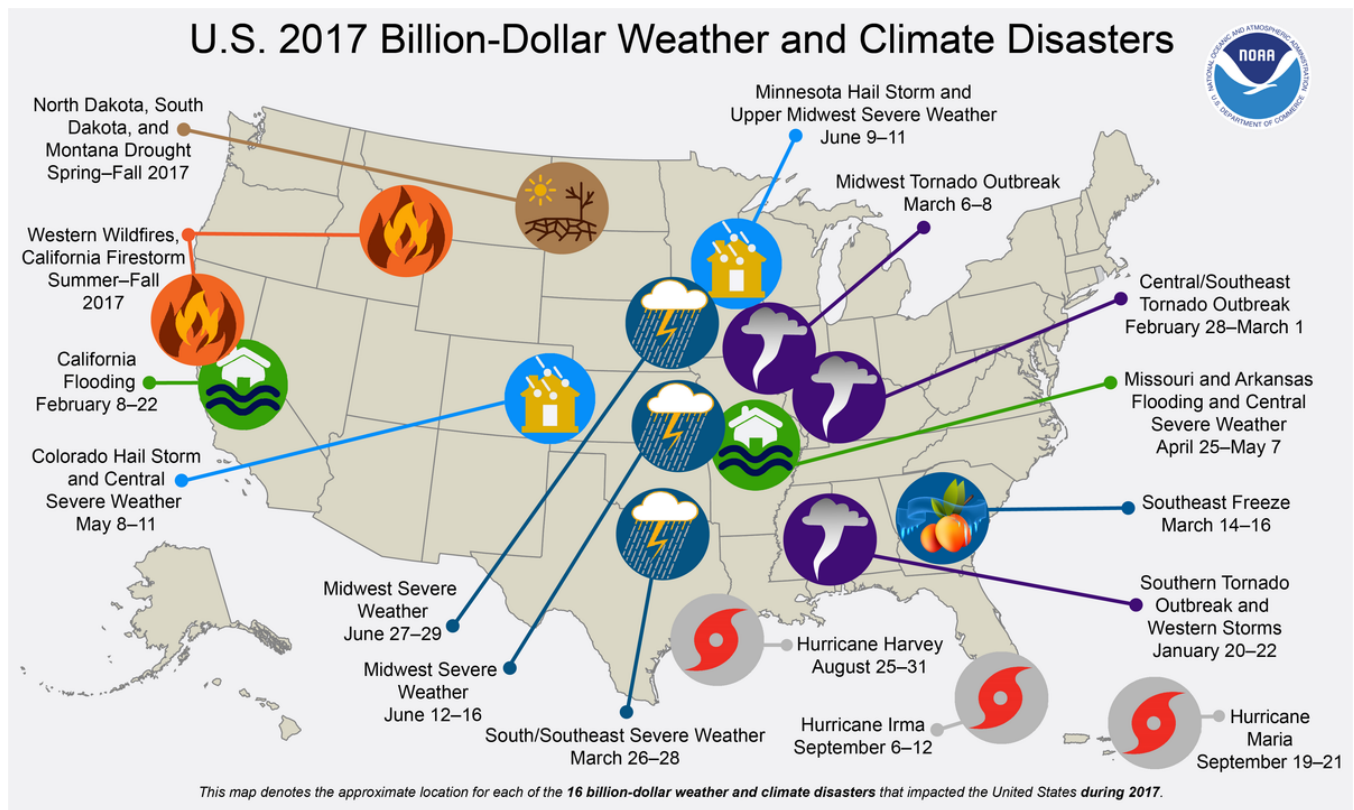


Figure 4 US 2017 Billion-Dollar weather and Climate Disaster. (NOAA)

As shown in Figure 3, the year 2017 had an historically high number of billion-dollar disasters that impacted the United States economy. The total cost of the natural disasters damage was approximately 306 billion dollars (5). During such devastating periods as this,

Federal funding can be limited, especially at the individual or family level, and Non-Governmental organizations such as the Red Cross, All Hands and Hearts, church groups, and World Renew can offer financial assistance to victims who are struggling to replace necessary items or make home repairs not covered by insurance.

In the wake of Hurricane Irma and Hurricane Maria in the USVI and Puerto Rico, there were many organizations involved in saving lives, supporting and feeding the survivors in addition to federal assistance. The American Red Cross served over 594,000 meals, delivered 324,000 relief items and provided 10,400 mental health and other health services to the survivors. The Salvation Army distributed 26,000 meals-ready-to-eat and sent containers of clean water to the USVI (31). Other organizations such as All Hands assisted by removing debris and rebuilding schools that were damaged by the hurricanes.

Collaboration between the government, non-governmental agencies and the community is the key to smart response.

Community Involvement Gap

Community preparedness participation is a very recent phenomenon. Emergency management officials train and educate the business sectors and other interested volunteers from the community. One of the established groups of trained volunteers are the community emergency response team (CERT). In 1985 the Community Emergency Response Team concept was developed by the Los Angeles Fire Department (32). CERT was designed to educate the community and give an overview of disaster preparedness and response. This group can assist with an immediate response or long term mitigation strategy. In 1993 FEMA started CERT training in all 50 States, all US territories and District of Colombia to anyone interested in

disaster management/emergency preparedness (33). Most of the time CERT training is provided by FEMA in collaboration with the Red Cross.

Although training is available, there is a gap between community participation and emergency preparedness. In general, there is a lack of interest to learn about emergency preparedness unless people have previously been affected by a disaster. Another reason for the gap in community participation is that it is difficult to manage spontaneous unaffiliated sponsors at the time of crisis. Spontaneous unaffiliated volunteers (SUV) are volunteers that have not been affiliated with a well-established organization before a disaster. Many volunteers arrive at disaster sites to help and are turned away by officials because they were not trained before the disaster and would only add to the challenge of an already complex environment. Training takes time and is very costly. There are organizations like All Hands and Hearts that takes unskilled volunteers and provide training and utilize work with volunteers.

Mitigation and resilience

FEMA defines hurricane hazard mitigation as an effort to reduce damage to property and also reduce the loss of life caused by disasters. The key strategy of any disaster management is to reduce vulnerability. As the intensity and frequency of weather events increase along with burgeoning coastal populations, the cost of disaster response has skyrocketed. The goal of a hurricane mitigation plan is to build disaster proof infrastructures that are resistant to future disaster and advise people who live on a flood plain or disaster-prone area to consider moving to a different location (34).

The storm surge that occur as a hurricane makes landfall causes most of the damage as the rising flood waters inundate facilities and destroys property and infrastructure along the

coastline. Hurricane mitigation plans are challenging to implement because the materials needed to build disaster-proof structures are expensive.

Lesson learned from Hurricane Maria and Hurricane Irma

Hurricane Harvey, Hurricane Irma, and Hurricane Maria made 2017 the most difficult year for Texas, Louisiana, United States Virgin Islands and Puerto Rico. Some of the major challenges faced during and after Hurricane Irma and Hurricane Maria were caused by a lack of focus on the vulnerable populations during the preparedness planning. Most of the plans of hurricane preparedness are in place based on the needs of the community as a whole, with a lack of focus on vulnerable populations that sometimes had specific needs. According to the Center for Disease Control MMWR report, six days after Hurricane Maria, 84% of the hospitals in Puerto Rico neither had electricity nor fuel for generators that left some ICU patients dead (35). Lack of power also meant a lack of air conditioning, and a lack of air conditioning could be deadly in mid-September. One study found that 13% of deaths after the Hurricane Maria were heat-related (36).

Absent street names and addresses prevented FEMA rescuers from being able to help people living in St. Croix. Saving lives is one reason why the territory needs a comprehensive and easy-to-understand address system.

Public health relevance

According to the American Public Health Association definition, public health promotes the health of people and the communities where they live, learn, work and play (37). Hurricanes are an important public health problem that threatens public wellness. As the frequency and the

intensity of hurricanes increase, there has been a growing negative impact on public health and wellbeing.

When a hurricane make landfall, it causes significant damage to road infrastructure which limits transportation, causes power outages and disrupts communication. Most small clinics in the community do not have the capacity to use generators to continue service, and as a result, most health care centers close. Right after the devastating category 4 Hurricane Maria, Puerto Rico's healthcare facilities suffered a major power outage and were forced to refer patients with critical conditions. Charles Hardwood complex is one of the many hospitals that resisted the heavy wind and flooding, but nine months later the building was infested by mold and the building was demolished.

Hurricanes not only creates physical destruction but also contributes a mental burden. After hurricanes pass, people experience trauma and devastation which could lead to a short and long term effects.

The effect of hurricane on mental health

Mental health is largely the forgotten in the aftermath effect of a hurricane. A natural disaster like Hurricane Irma, Hurricane Maria, and Hurricane Harvey leave communities with mental illness such as post-traumatic depression stress disorder (PTSD) chronic depression, and anxiety. One study found that the prevalence rate of PTSD after a natural disaster ranges from 5% to 60%(38). After Hurricane Sandy, more than 20% of residents reported PTSD, 33% reported depression and 46% reported anxiety. Similarly, the University of Puerto Rico did a study prior to the two devastating hurricanes and found that 7.3% of the population was suffering from

severe mental illness (39). After hurricane Maria, Puerto Rico's Suicidal Hotline call usage increased by 246% from the previous year and also had 253 suicides which were 57 more suicided from 2016 (40).

Hurricane impact on the Environment

In addition to damaging homes, infrastructures and taking lives, hurricanes disturb the ecosystem. High winds with heavy rainfall damage trees leading to erosion, which drives landslides and wildlife migration. Hurricanes also indirectly lead to human-made disasters. During Hurricane Katrina, almost 50 oil spills were reported in the nearshore environment as well as in the metropolitan area of New Orleans (41). Some of the major oil companies such as Shell had over 1 million gallons of discharge. The oil spill directly affected the aquatic life which later caused a decrease in the fish production revenue. Almost 14 years later, the aftermath of the spill is still felt in the coastal areas of Louisiana (41). In Southeast Louisiana, the United States Food and Drug Administration (USDA), Environmental Protection Agency (EPA) and NOAA still monitor samples of fish and shellfish for chemical contamination. Hurricane Irma and Hurricane Maria left over 700,000 cubic yards of debris on the USVI (42).

Brief review on public health and emergency preparedness

Hurricane related Infectious diseases

Hurricane related infectious diseases are a major concern to the community following hurricanes. Diarrheal disease is common in the aftermath of storms due to limited access to clean water and high flooding. Floodwaters contain many microorganisms that may harm human and animal health. Some floodwaters are contaminated with human and livestock waste, downed power lines, wild and stray animals such as snakes and rodents, carcinogenic compounds,

debris, and sharp objects (43). Most of the time, exposure to contaminated floodwater leads to skin rashes, gastrointestinal illness, tetanus (if not vaccinated within ten years of the exposure), wound infections, and new or a reintroduction of new infectious diseases. In the wake of hurricane Maria and Hurricane Irma, a case of leptospirosis (n = 1) and melioidosis (n = 2) were recorded in the United Virgin Islands for the first time (44).

Leptospirosis

Leptospirosis is a bacterial (spirochete) disease that is caused by the genus *Leptospira*. Leptospirosis is spread through the urine of infected animals, which can get into the water during flooding and can survive for weeks to months (45). The bacteria can enter the body through the skin (open wound), eyes, nose, or mouth. If the bacteria is left untreated, it can cause kidney failure, meningitis, liver failure, respiratory distress, and even death (Citation). In other similar events, although Puerto Rico is not new to Leptospirosis at least 26 people died of this disease within six months after Hurricane Maria (46).

Vector-borne disease

The rise of vector-borne diseases are an additional concern in the after-math of a hurricane. Vector borne diseases are transmitted through a bite of an infected mosquito. Mosquitos prefer warm and humid (moist) climate to reproduce. Although adult mosquitos cannot survive high winds during hurricanes, soon after the hurricane is over, flooding occurs which is an ideal breeding ground for mosquitos. Mosquitos generally lay their eggs in the soil by floodwater and generally it is expected for an increases in mosquito population right after a hurricane (47).

In addition to the increased population of mosquitos after hurricanes, people are more vulnerable to mosquitoes after hurricanes than at other times. Most major hurricanes occur during months between August and October; this is the hottest time of the year. Hurricanes also cause power outages, which leads to no air conditioning and because of that, people are more inclined to wear short sleeve shirts and shorts which increases their chances of getting exposed to mosquitos. After hurricanes damage, people tend to spend more time outside cleaning up after a hurricane or flood, which increases the chance of getting bitten by mosquitos.

As a result, the community, local health officials, governmental and other non-governmental organizations should work together and monitor the flood. Education plays an important role in controlling vector borne diseases. Applying insect repellent as needed, wearing long sleeved shirts and long pants at all times and if possible sleep under a bed nets will decrease the population of infected mosquitos and results in reduction in prevalence rate of vector borne diseases (47).

Recommendations

As it is almost impossible to be fully prepare for a disaster, it essential that there is a preparedness plan in place. After spending a little more than two months (May 20th,2019 thru August 10th, 2019) in the United States Virgin Islands, the followings are my recommendations for a preparedness plan. The population in the United States Virgin Islands is vulnerable for hurricanes as it located in Hurricane Alley.

- I believe incorporating CERT training as a mandatory course in high schools and universities would better prepare the community for future disasters.

- Street names with GPS coordinates are important for non-local responders to locate survivors after a disaster.
- St. Croix needs a publicly accessible and funded mental health clinic. Disaster preparedness efforts should involve increasing mental health resources to those who are displaced and providing support services within the shelter setting.
- Relocating communities that lives in close to the coastal areas.
- Cleaning abandoned houses to avoid being a mosquito breeding ground
- Conducting regular awareness campaigns and public service announcements, on hurricane preparedness every hurricane season.
- Design a table top exercise that would allow the local community to participate and learn. The tabletop exercise could also be used to identify any gaps in the preparedness plan that needs to be addressed for future disaster planning efforts.

Conclusion

Natural disasters such as Hurricanes are not new to The United States Virgin Islands. Over the past decade. The frequency and intensity of these hurricanes have increased but the emergency preparedness, response and recovery plans have not been updated. The degree to which residents and the community as a whole, prepare prior to a hurricane making landfall is critical to reducing the damage and destruction brought about by the storm.

Two years after a Category 5 hurricanes ravaged the United States Virgin Islands, they are still in the recovery phase. The purpose of this special project is to examine the relationship between governmental, non-governmental, local community responders, and other disaster relief organizations during hurricane preparedness, response and recovery. It is essential that these stakeholders work in tandem to aid in the better implementation of response efforts. At

the moment there is a lack of collaboration between the different levels of government and the aforementioned stakeholders. This has been compounded by a general lethargy in developing new and updated evacuation plans before a hurricane makes landfall and rescue and reconstruction work after the disaster. Also, there is a gap in effective community involvement and management of unaffiliated sponsors and volunteers at the time of crisis.

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