Building Action for Emergency Preparedness and Well-being (CAPBRACE)

# CLIMATE IMPACT COMPENDIUM

Puerto Rico Public Health Trust

A program of: Puerto Rico Science, Technology & Research Trust

U.S. CENTERS FOR DISEASE CONTROL AND PREVENTION

# TABLE OF CONTENTS

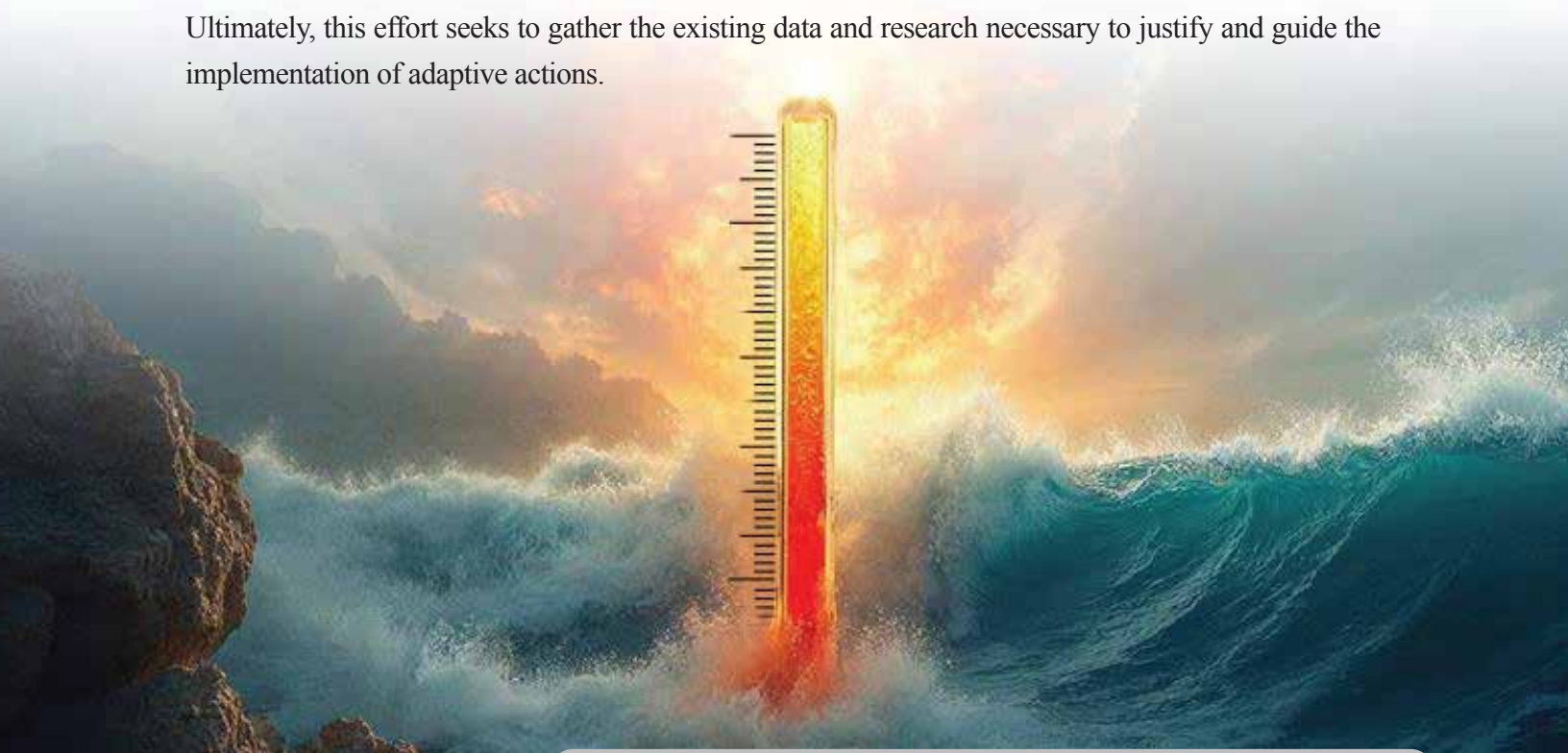
# INTRODUCTION

Climate change presents exceptional challenges to natural resources and public health. Rising temperatures (atmospheric and oceanic) and carbon dioxide concentrations make it more difficult to meet environmental quality standards necessary to protect the most vulnerable populations and ecosystems. Many models point to an acceleration of the hydrological cycle in a warmer climate with severe impacts on the frequency and occurrence of extreme events.

The health and economy of the states and territories like Puerto Rico are particularly vulnerable to extreme situations, climate change, atmospheric conditions, and marine-coastal hazards. Without effective responses, Climate Change will jeopardize the quality of coastal and inland waters, food security and infectious disease control, extremely increasing the population at risk. To protect the population and to be able to develop strategies that promote protection of communities, better models are needed to accurately understand the effects of climate change on Puerto Rico. For this reason, it is urgent to fully understand the dynamics and natural processes that foster these changes. In this context, the scientific community is advancing in this discipline, and several studies and models have been developed. However, there are still large gaps.

The study of observed and projected climate-related trends provides information to assess the climate and environmental consequences of future climate changes, risks and impacts.

By examining observed and projected climate-related trends, we can better assess the environmental and health consequences of climate change. This compendium aims to synthesize and update findings regarding local climate forecasts, current and potential health impacts including health disparities affected by systems, and social determinants of health contributing to these disparities. Additionally, it will explore adaptive capacity in relation to climate hazards pertinent to stakeholders. Ultimately, this effort seeks to gather the existing data and research necessary to justify and guide the implementation of adaptive actions.



# LOCAL CLIMATE FORECAST FOR PUERTO RICO:
# ASSESSING VARIABILITY AND PROJECTIONS

## CLIMATE VARIABILITY

Natural climate variability, including phenomena such as the El Niño–Southern Oscillation (ENSO), the North Atlantic Oscillation (NAO) and Saharan dust events, has an important role in interannual (year-to-year) and sub-seasonal climate patterns within the Caribbean region (Méndez-Lázaro et al., 2023; Jay et al., 2023).

## TEMPERATURE PROJECTIONS

Average daily temperatures in Puerto Rico have increased 2°F since 1950. Minimum temperatures are rising faster than average daily temperatures, with the largest increase being recorded in minimum temperatures in lower areas. Projections for end-of-century temperatures show additional warming, from 1.1 °F in an intermediate scenario (shared socioeconomic trajectory SSP2-4.5) up to 7°F in a very high scenario (SSP 5-8.5) (Calo et al., 2022; Méndez-Lázaro et al., 2023).

## PRECIPITATION TRENDS

No clear long-term trend is detected in the average seasonal or annual rainfall in PR. However, climate models project a significant reduction in average annual rainfall by the end of the century, with reductions of 10% for SSP2-4.5 and 33% for SSP5-8.5. Precipitation reductions for SSP5-8.5 compared to SSP2-4.5 are increasing after mid-century. The consequence of the reduction in average annual rainfall is a large increase in the number of consecutive dry days, especially in the wet season (Ortíz et al., 2020; de Ángel Solá et al., 2020).

## TROPICAL CYCLONES

In the Atlantic basin, the tropical cyclone precipitation rate is projected to increase by about 15% and the average intensity of storm winds by about 3% for a global average temperature increase of 3.6°F (2°C) above current levels. The number of severe tropical cyclones (category 4 and 5) is also projected to increase. There are indications in Puerto Rico that tropical cyclone precipitation rates are increasing with respect to the climatological record, which increases the probability of extreme events such as the rains of Hurricane Maria. Sea surface temperatures have warmed, and the oceans are acidifying, absorbing higher concentrations of atmospheric carbon dioxide (CO2) (Holladay & Méndez-Lázaro, 2021; Gould et al., 2018).

## SEA LEVELS

Sea levels are rising and are projected to continue rising for centuries. Long-term sea level scenarios indicate an additional rise of about 0.6 feet (0.2 m; low scenario) to 1.4 feet (0.4; high scenario) by 2050 and from 1.9 feet (0.4 m; low scenario) to 6.8 feet (2.1 m; high stage) for 210025; for connections to shared socioeconomic trajectories (SSPs), see the Report Guide. The trajectory of tide gauge observations in the U.S. Caribbean archipelago between 1970 and 2020 coincides with the intermediate scenario until 2050 (Gould & Díaz, 2018; de Ángel Solá et al., 2020).

## HEALTH IMPACTS

Extreme weather events are expected to exacerbate inequalities, deteriorate marine and terrestrial ecosystems while impacting the health and well-being of Puerto Ricans (Méndez-Lázaro et al., 2021; Johnson et al., 2023).

### *Access to Services:*

Extreme events, combined with deteriorating infrastructure and the unequal distribution of social determinants of health, are expected to continue to lead to disruptions and insufficient access to health care services (Méndez-Lázaro et al., 2021; Calo et al., 2022).

### *Vector Borne Diseases:*

The abundance of Aedes aegypti and Aedes albopictus, key vectors of diseases such as dengue, Zika, and chikungunya, is strongly influenced by temperature and rainfall. Both species have an excellent ability to adapt to extreme temperature and precipitation conditions. Factors contributing to vector borne diseases outbreaks in the Caribbean include climate change, inequality, poverty, serotype profile (virus variation), immunity, inefficient water and waste management, and lack of community awareness (Laureano-Rosario et al., 2018; de Jesús Crespo et al., 2018).

### *Zoonotic Diseases:*

Recent evidence suggests an excess risk of leptospirosis in Puerto Rico associated with areas prone to floods, torrential rains, and higher temperatures. It is expected that extreme weather events such as tropical storms, torrential rains and floods lead to an increase in the number and magnitude of leptospirosis outbreaks (Napoli et al., 2021; de Ángel Solá et al., 2020).

### *Extreme Heat:*

Extreme heat conditions in the Caribbean have intensified since 1980. Recent research suggests an increasing trend in the number of heat-stressed days for the Caribbean region since 1980. Several factors contribute to heat vulnerability and sensitivity, including populations at the extremes of age (e.g., newborns, children, and older adults), pregnant women, and individuals who: live in single-person households, live below the poverty line, work in confined spaces with poor ventilation, work outdoors with direct exposure to sunlight or high humidity combined with extremely high air temperature, live with disabilities, or suffer from chronic health conditions such as obesity, hypertension, diabetes, cardiovascular diseases, and respiratory disorders Furthermore, lack of health insurance coverage exacerbates vulnerability. (Méndez-Lázaro et al., 2023; Calo et al., 2022).

In San Juan, PR there is already evidence of these effects and Heat Islands. Extreme heat episodes have been associated with a significant increase in mortality and a higher relative risk of stroke and cardiovascular disease in Puerto Rico (Holladay et al., 2019).

### *Sahara Dust:*

Studies suggest that global warming will intensify dust storms in the Mediterranean and Atlantic. Dust particles transported across the Atlantic from the Sahara, particularly during the summer, affect climate, weather conditions and ecosystems, including coral reefs, forests and human populations. In PR, Saharan dust has been associated with increased cardiovascular and respiratory risks (Tong et al., 2021; Méndez-Lázaro et al., 2023).

### *Sargassum:*

Sargassum events threaten coastal ecosystems and social and cultural activities (e.g., fisheries), with negative economic impacts (e.g., reduced tourism and degradation of infrastructure) and adverse effects on human health (e.g., palpitations, shortness of breath, and rash) due to airborne hydrogen sulfide from decaying sargassum and direct exposure to algae (Laureano-Rosario et al., 2018; Méndez-Lázaro et al., 2017).

### *Excess mortality:*

Puerto Rico is a tropical island located in the northern-central Caribbean Sea, spanning an area of approximately 8,900 km² and comprising 78 municipalities. The San Juan Metropolitan Area experiences a subtropical humid climate, with weather patterns that shift more gradually during the summer months compared to the winter. A relatively dry period occurs during the winter months, including June and July, while the wet seasons typically take place in May and autumn (Colón-Torres 2009; Méndez-Lázaro et al. 2014a, b).

Extreme heat episodes, characterized by their intensity, duration, and frequency, pose significant risks to human health by causing heat stress and worsening underlying conditions, which can lead to increased mortality rates (Ebi and Meehl 2007; Portier et al. 2013).

***Non-communicable diseases:***

Noncommunicable diseases (NCDs), often referred to as chronic diseases, are long-lasting conditions that are not transmissible from person to person. Common examples of NCDs include mental health disorders, cardiovascular diseases, cancer, diabetes, and chronic respiratory diseases. According to the World Health Organization, NCDs are responsible for 41 million deaths annually, with the majority attributed to cardiovascular diseases, cancer, chronic respiratory conditions, and diabetes.

The Caribbean region bears the highest burden of noncommunicable diseases (NCDs) among developing nations in the Americas, with NCDs being the leading cause of death. In Puerto Rico alone, a total of 27,240 deaths were attributed to NCDs in 2021. Of these, 7,644 were caused by cardiovascular diseases, 5,207 by cancer, 4,314 by diabetes, and 4,754 by neurological conditions.

## SOCIAL VULNERABILITY INDEX (SVI)

Communities facing poverty, limited transportation, and overcrowded housing are at greater risk during disasters. Identifying these vulnerabilities is essential to address health disparities from climate hazards. Using the Centers for Disease Control and Prevention (CDC) SVI, we can pinpoint the most vulnerable municipalities in Puerto Rico. The SVI is a tool that assesses the social vulnerabilities of communities by considering factors such as socioeconomic status, household characteristics, and housing conditions. The index is scored on a scale from 0 to 1, with higher scores indicating greater vulnerability to the impacts of climate hazards and disasters.

The following municipalities in Puerto Rico have the highest SVI scores, indicating they face significant vulnerabilities:

- Loíza (1.0)
- Fajardo (0.987)
- Mayagüez (0.974)
- Ponce (0.961)
- Arroyo (0.948)

These municipalities are assessed on factors such as socioeconomic status, household characteristics, and housing conditions, highlighting how social determinants affect health disparities during extreme weather (Agency for Toxic Substances and Disease Registry, 2022).

SVI TOOL:
***https://www.atsdr.cdc.gov/place-health/php/svi/svi-interactive-map.html?CDC_AAref_Val=https://www.atsdr.cdc.gov/placeandhealth/svi/interactive_map.html***

## CENSUS BUREAU'S CLIMATE RESILIENCE ESTIMATE TOOL (CRE)

The Community Resilience Estimates (CRE) for Puerto Rico offers a clear metric for assessing a community's ability to endure and recover from disasters like hurricanes (U.S. Census Bureau, 2020). This initiative, part of the broader Community Resilience Estimates Program, utilizes microdata from the Puerto Rico Community Survey (PRCS) to evaluate social vulnerability at various geographic levels. Vulnerability is assessed using ten PRCS indicators, including poverty status, disability, caregiver numbers, housing crowding, vehicle access, broadband internet, employment, education, age, and health insurance coverage.

All municipalities in Puerto Rico show low levels of resilience compared to the United States, but some have particularly high rates of vulnerability with three or more risk factors: Maricao (65.0%), Lajas (63.3%), Guánica (62.3%), Sabana Grande (57.0%), and Ciales (56.4%) (U.S. Census Bureau, 2020.).

CRE TOOL:
***https://www.census.gov/programs-surveys/community-resilience-estimates/data/cre-pr.html***

## THE ATLAS OF THE FIFTH NATIONAL CLIMATE ASSESSMENT (NCA5)

The NCA Interactive Atlas offers digital access to detailed climate projection maps utilized in the Fifth U.S. National Climate Assessment (NCA5) This tool allows users to explore climate data at the census tract level, including the Justice 4.0 Tracts, which identify disadvantaged communities based on updated criteria that integrate factors like income, race, access to healthcare, and environmental hazards (U.S. Global Change Research Program, 2023). This resource is essential for understanding and addressing the unique climate challenges faced by Puerto Rico's vulnerable populations.

NCA5 ATLAS TOOL: ***https://atlas.globalchange.gov/pages/about-atlas***

## ALL COMMUNITIES ARE A PRIORITY IN PUERTO RICO

According to Germanwatch's 2021 Global Climate Risk Index. Puerto Rico is among the most affected regions globally by extreme weather events from 2000 to 2019, largely due to the catastrophic impact of Hurricane Maria in 2017. As of 2023, impoverished populations continue to grapple with the social and economic devastation left in the wake of this hurricane (Eckstein, Künzel, & Schäfer, 2021).

In 2017, Puerto Rico's population was approximately 3.4 million, but by 2021, it had dropped to about 3.263 million, according to U.S. Census estimates. Notably, the demographic profile reveals that a larger portion of the remaining population is increasingly vulnerable: the percentage of residents aged 65 and over rose from 18% in 2017 to 21.3% in 2021 (U.S. Census Bureau, 2020).

## HEALTH IMPACTS OF CLIMATE CHANGE

### *Zoonotic diseases*

A zoonosis is any disease or infection that is naturally transmissible from vertebrate animals to humans. Zoonotic pathogens may be bacterial, viral or parasitic or may involve unconventional agents and can spread to humans through direct contact, food, water or the environment (World Health Organization [WHO], 2020).

***Leptospirosis***

Leptospirosis is a disease caused by the bacterium Leptospira that can be found in contaminated water and soil (WHO, 2020). It can affect animals and human beings. It is an acute febrile illness with varied manifestations. The severity of the disease ranges from asymptomatic or subclinical to a self-limiting systemic disease. Some of the signs and symptoms are:

- Fever
- Headache
- Child
- Body or muscle aches
- Vomiting or nausea
- Yellowed skin and eyes
- Red eyes
- Stomach pain
- Diarrhea
- Rash

The bacteria that cause leptospirosis are spread through the urine (pee) of infected animals. The bacteria can survive in contaminated water or soil for weeks to even months. Many kinds of wild animals and domestic animals can carry the bacteria, including the following:

- livestock (cows, pigs, horses, sheep, goats, etc.)
- dogs
- cats
- rodents (rats, mice, etc.)
- marine mammals (sea lions, seals, etc.)
- wild animals (zoo animals, wild pigs, etc.)

Leptospirosis has emerged as a global epidemic in impoverished urban communities and is increasingly being recognized as an important cause of disaster-associated outbreaks exemplified by large epidemics after seasonal rainfall in places such as Brazil and hurricanes in Central America and Puerto Rico (WHO, 2020). After Hurricane Maria struck Puerto Rico in 2017, many deaths were attributed to this disaster and the identification of leptospirosis as a cause of hurricane-associated mortality, emphasizing the disease as a health problem in the archipelago (Centers for Disease Control and Prevention [CDC], 2024). In Puerto Rico, leptospirosis is considered an endemic disease, with significantly higher infection risks in areas with continuous exposure to contaminated water. A 2015 study in Caño Martín Peña revealed a seroprevalence of 27.2% among participating residents (CDC, 2024). Additionally, exposure during flooding and natural disasters, such as hurricanes and heavy rainy seasons, further elevates the risk of leptospirosis in the population (WHO, 2020).

According to the Puerto Rico Department of Health (PRDoH), the incidence rate of leptospirosis cases is 0.69 for every 100,000 inhabitants from January 1st, 2023, to June 30th, 2024. For the period of January 1st, 2024, to June 30th, 2024, there have been a total of 142 cases of Leptospirosis reported. The average number of cases reported during this period was 5.5 cases per epidemiological week. The municipalities with the greater amount of incidence rate were Adjuntas, Aibonito, Maricao, Orocovis y Cidra. During the same period, 6 deaths were associated with leptospirosis. (Puerto Rico Department of Health [PRDoH], 2024).

### *Vector diseases*

Vector-borne diseases are human illnesses caused by parasites, viruses and bacteria that are transmitted by vectors (WHO, 2020). Vectors are living organisms than transmit pathogens between humans or from animals to humans. Most of these vectors are bloodsucking insects, which ingest disease-producing microorganisms during a blood meal from an infected host (human or animal) and later transmit it into a new host. For example, mosquitoes, aquatic snails, blackflies, fleas, lice, sandflies, ticks, among many others.

### *Arboviral diseases*

#### *Dengue fever*

According to the World Health Organization (WHO, 2020), dengue, also known as break-bone-fever, is a viral infection that spreads from mosquitoes to people. Specifically, through the bite of infected Aedes species mosquitoes (Ae. Aegypti or Ae. Albopictus). It is common in tropical and subtropical climates. There are four different dengue-related virus types: dengue-1, dengue-1, dengue-3 and dengue-4. These mosquitoes typically lay their eggs in containers that hold water like buckets, bowls, animal dishes, flowerpots and vases (Sanders et.al, 1999). Most people with dengue can have

mild or no symptoms. Some of the symptoms can include:

- High fever
- Severe headache
- Pain behind the eyes
- Muscle and joint pains
- Nausea
- Vomiting
- Swollen glands
- Rash

Studies have shown that climate significantly influences the seasonal variation and global distribution of dengue fever. Factors such as temperature, rainfall, humidity along with their interactions, impact mosquito population dynamics and the cycles of disease transmission (Abdullah, Dom, Salleh, Salim, & Precha, 2022).

The global incidence of dengue has increased over the past three decades with large and periodic epidemics in endemic areas (Stanaway et al., 2016). According to the CDC, dengue fever affects up to 400 million people globally each year, with approximately 100 million falling ill and 40,000 dying from severe forms of the disease. Data from the Pan American Health Organization (PAHO) reveal a significant increase in dengue cases in the Americas over the past four decades, rising from 1.5 million cases in the 1980s to 16.2 million cases between 2010 and 2019.

According to the PRDoH, the number of dengue cases was 1,293 during the period January 1st to December 31st, 2023. For the period of January 1st, 2024, to August 11th, 2024, there has been a total of 2,704 dengue cases reported. The municipalities with the greater number of cases were San Juan, Carolina, Rincon, Bayamon and Aguada. During the same period, 3 deaths were associated with dengue (DENV-3) (PRDoH, 2024).

***Chikungunya***

Chikungunya is a mosquito-borne viral disease caused by the Chikungunya virus (CHIKV). The virus is transmitted mostly by the mosquito Aedes aegypti or Aedes albopictus, which can also transmit dengue and Zika viruses. CHIKV was first identified in the United Republic of Tanzania in 1952 and in other countries such as Africa and Asia. Since 2004, outbreaks of chikungunya have become more

common and widespread, caused partly due to viral adaptations allowing the virus to be spread more easily by Aedes albopictus mosquitoes (World Health Organization, 2022). The first case of Chikungunya in Puerto Rico was reported in 2014, marking the year when the island experienced its first epidemic (Department of Health, 2024). People infected with Chikungunya virus can develop some symptoms that can begin between 3 to 7 days after the mosquito bite (CDC, 2024). The most common symptoms are fever and joint pain. But people can also experience the following symptoms:

- Muscular pain
- Headache
- Nausea
- Fatigue
- Cutaneous eruptions

Climate change can also have an impact on the occurrence of Chikungunya cases among the population. Extreme events such as hurricanes, heat waves and flooding promote the spread of vector-borne diseases. An increase in temperatures can also increase vector and pathogen metabolism allowing faster replication and spread, whereas erratic rainfall patterns may increase the availability of suitable breeding sites (Filho et al., 2019). These trends can expand the transmission season in tropical and sub-tropical areas.

According to them, the number of chikungunya cases was 46 during the period January 1st to December 31st, 2023. No cases have been reported during the period of January 1st, 2024, to August 11th, 2024 (PRDoH, 2024).

***Zika***

Zika virus is a mosquito-borne virus that was first reported in Uganda in 1947, followed by evidence of infection and disease in humas in other African countries during the 1950s (WHO, 2022). In 2015, the first outbreak of Zika in the Americas was reported, including Puerto Rico (PRDoH, 2024). Even though Zika cases have declined globally since 2017, the virus transmission persists at low levels in several countries in the Americas and in other endemic regions.

Most of the people infected with Zika virus do not develop symptoms. Those who have reported symptoms typically appear 3 to 14 days after the infection and are generally mild including rash, fever, conjunctivitis, muscle and joint pain, malaise and headache.

Like the other vector-borne diseases, changing in thermal conditions can result in an increase of the vectors. Warming temperatures can significantly increase thermal suitability for the ZIKV transmission in different places around the world. There is an estimate that over 1.3 billion people would likely be exposed for the first time to temperature conditions suitable for Zika transmission (Ryan et al., 2020).

According to the Puerto Rico Department of Health, the number of Zika cases was 46 during the period January 1st to December 31st, 2023. For the period of January 1st, 2024, to August 11th, 2024, there has been a total of 16 cases reported. The municipalities with the greater number of cases were Carolina, Rincon and Bayamon. No deaths were reported during this period (PRDoH, 2024).

Weekly Arboviral Diseases Report: ***Dengue, Chikungunya, and Zika Cases - Puerto Rico Department of Health: https://www.salud.pr.gov/CMS/365***

## *Extreme heat*

Extreme heat is defined by the CDC as summertime temperatures that are much higher and/or humid than average. Since some places are hotter than others, it will depend on what is considered the average temperature for a particular location at that time of the year. According to reports from the National Weather Service (NWS), since early May there has been a significant rise in heat indices, frequently surpassing the maximum recorded temperatures. Older adults, infants and children, individuals with chronic health conditions, low-income populations, athletes, and outdoor workers are the groups most vulnerable to the adverse effects of exposure to high temperatures (CDC, 2019).

In Puerto Rico, the Department of Health operates a Syndromic Surveillance System in collaboration with the National Syndromic Surveillance Program (NSSP), using data from the CDC as its primary source. This system gathers medical records from emergency rooms and urgent care visits at healthcare facilities, such as hospitals and diagnostic and treatment centers (CDTs). The data is reported to the Puerto Rico Department of Health via the Electronic Surveillance System for the Early Notification of Community-based Epidemics (ESSENCE), which serves as the main platform for data collection, storage, and analysis. As of June 2024, 26 facilities are regularly reporting syndromic information to the Department of Health, representing 13.9% of the emergency rooms in the archipelago.

The illness related to heat or light alone reported through this system are the following:

- Sunburn
- Effects of heat and light
- Heatstroke and sunstroke
- Heat syncope
- Heat cramp
- Heat exhaustion, anhidrotic
- Heat exhaustion due to salt depletion
- Heat fatigue
- Heat edema
- Exposure to excessive natural heat
- Exposure to sunlight

Between January 2023 and June 2024, the Puerto Rico Department of Health received a total of 344 notifications, with the majority coming from municipalities in the Caguas, Arecibo, and Bayamon regions. The highest number of notifications occurred in June 2023 and May 2024 (PRDoH, 2024).

Syndromic Surveillance System: Heat or Light-Related Events - ***Special Bulletin #80 (Epidemiological Weeks 1-52 2023, Weeks 1-49 2024): https://www.salud.pr.gov/CMS/DOWNLOAD/9531***

## *Hurricanes*

Puerto Rico is in the Caribbean with a tropical climate and is yearly exposed to tropical storms like hurricanes. More than 15% of all Atlantic hurricanes in any given year impact the Caribbean Antilles, including Puerto Rico. According to the National Hurricane Center (NHC, 2022), this region averages 1.1–1.9 named tropical cyclones per year, leading to disaster-induced displacement or evacuation orders for these small, isolated islands. These storms often bring high winds, storm surges, intense rains, flooding, and landslides to the islands.

On September 18th, 2022, hurricane Fiona hit the southwestern area of Puerto Rico, causing flash floodings, mudslides and leaving the entire island without power.

After an atmospheric event, part of the public health response involves determining whether a death is related to the disaster. Deaths can be classified as directly or indirectly related. According to the CDC, a directly related death is one attributable to the immediate forces of the disaster, such as structural collapse, flying debris, or radiation exposure. In contrast, an indirectly related death occurs due to unsafe or unhealthy conditions present during any phase of the disaster response or recovery, such as lack of access to medical care or exposure to hazardous environments (National Center for Health Statistics, 2017).

As of January 2023, the Puerto Rico Department of Health reported a total of 44 deaths related to Hurricane Fiona. Figure 1 shows the classification of the deaths reported.

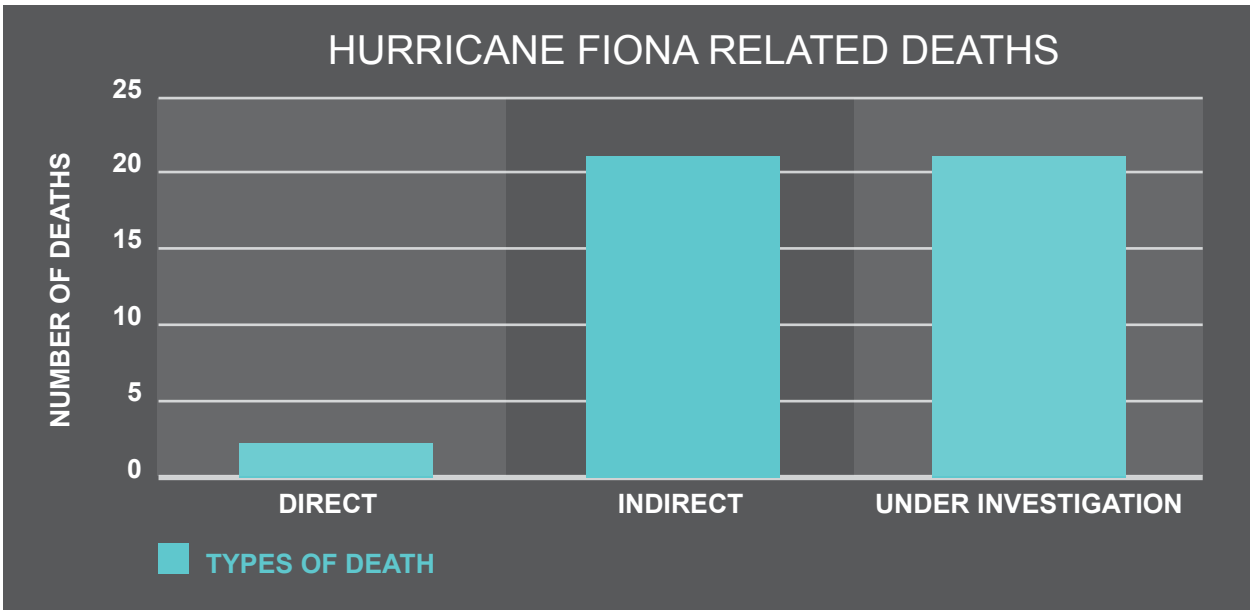



***Figure 1: Hurricane Fiona related deaths, source PRDoH***

Additionally, on September 20th, 2017, Hurricane Maria made landfall in Puerto Rico with winds of 249 kilometers per hour. This hurricane caused an estimated $90 billion in damages, making it the thirds costliest tropical cyclone in the United States since 1900. People were displaced from their homes, seeking shelter elsewhere around the archipelago or on the mainland United States. In the early December 2017, the official death count was 64 (Pascual, 2017)., but other investigations concluded that additional deaths attributable to the hurricane were more than 1,000 in the months of September and October. On December 18, the Government of Puerto Rico ordered a recount and on February 22, 2018, it announced that George Washington University oversaw it. Their study was published on August 27 and established that there had been 2,975 excess deaths due to the hurricane. This number was accepted by the Government of Puerto Rico (Harvard T.H. Chan School of Public Health, 2019).

**Research Article: Mortality in Puerto Rico after Hurricane Maria**

A special article in The New England Journal of Medicine indicates an estimate of 4,645 excess deaths from September 20 through December 31, 2017, after Hurricane Maria, which remained high throughout the following years. The main cause was healthcare disruption, particularly for individuals with chronic diseases who relied on sophisticated pharmaceutical and mechanical support dependent on electricity. This article highlights the need for chronically ill patients, their communities, and their providers to have contingency plans during and after disasters. (Kishore, N., Marqués, D., Mahmud, A., Kiang, M. V., Rodriguez, I., Fuller, A., Maas, L ... & Buckee, C. O. (2018). Mortality in Puerto Rico after Hurricane Maria. New England Journal of Medicine, 379(2), 162-170.)

**Research Article: Evacuation Decision Making During the COVID-19 Pandemic**

A research article examines risk perceptions and evacuation planning during the first hurricane season following the coronavirus disease 2019 pandemic before vaccines were widely available in Puerto Rico and the U.S. Virgin Islands.33 Key findings reflect that public shelter usage has the potential to decrease when the decision is coupled with COVID-19 threats, as individuals reported a negative perception of public shelter options.33 This highlights the need for future hazard mitigation planning during a disease outbreak or pandemic. (Collins, J., Polen, A., Dunn, E., Maas, L., Ackerson, E., Valmond, J., ... & Colón-Burgos, D. (2022). Hurricane hazards, evacuations, and sheltering evacuation decision-making in the prevaccine era of the COVID-19 pandemic in the PRVI region. Weather, Climate, and Society, 14(2), 451-466.)

**Research Article: Evacuation Decision-Making Post-COVID-19 Vaccine Availability**

The threat of novel pathogens and natural hazards is increasing as global temperatures rise, leading to more frequent and severe occurrences of infectious disease outbreaks and major hurricanes. The COVID-19 pandemic amplified the need to examine how risk perceptions related to hurricane evacuations shifted in Puerto Rico when vaccines became available. An overwhelming majority (72.6%) of respondents said that their vaccination status would not affect their hurricane evacuation intentions.34 However, those unvaccinated were significantly more likely to consider evacuating during a hurricane than the vaccinated. The likelihood of respondents utilizing a shelter during the 2021 hurricane season (40% “definitely would not” evacuate to a shelter) aligned with the likelihood prior to vaccine availability.34 There is a need for officials to develop and communicate clear information regarding evacuation orders and specific services offered at public shelters for certain municipalities

that may be more impacted than others based on the trajectory of the storm, social determinants of health, and other factors like living in a flood zone.34 (Hartnett, J.J., E.A. Dunn, J.M. Collins, L. Maas Cortes, R. Jones. Evacuation Decision-Making Post-COVID-19 Vaccine Availability: Implication of Compound Hazards in Puerto Rico and the US Virgin Islands. Weather, Climate, and Society. Submitted October 2023.)

**Research article: Assessing the Living Environment of Persons Displaced Following a Strong Earthquake Sequence in Puerto Rico, 2020**

A recent publication in the Journal of Emergency Management 487 Vol. 21, No. 6, November/December 2023 highlights results from a rapid needs assessment after a series of earthquakes in the South of Puerto Rico, titled: Assessing the living environment of persons displaced following a strong earthquake sequence in Puerto Rico, 2020. Authors: Miguel A. Cruz, PhD Richard Garfield, PhD Jessica Irizarry, PhD Norma I. Torres-Delgado, MHSA Melanie Z. Rodriguez-Rivera, MSHN Martin Montoya-Zavala, PhD Leslie Maas Cortes, MHS Gabriela Algarín, MPH Tesfaye Bayleyegn, MD Renee H. Funk, DVM Jose F. Rodriguez-Orengo, PhD Diego E. Zavala, PhD.

## MENTAL HEALTH

Natural disasters like hurricanes, flooding, and rising temperatures can lead to a surge in diseases, including cardiovascular conditions, diabetes, and mental health disorders. The Fifth National Climate Assessment highlights that climate change is expected to intensify the frequency and severity of hurricanes and other extreme weather events, which will likely result in increased illness, higher mortality rates, and a decline in overall quality of life for residents of Puerto Rico and the U.S. Virgin Islands (Marvell & Marvell, 2024).

Recent research has connected rising temperatures to increased violence, heightened stress levels, and diminished cognitive function. A study published in Nature Climate Change estimates that, if climate change continues at its current pace, the U.S. could see up to 21,000 additional suicides due to the mental health impacts of escalating heat.

According to the most recent Suicides Report, the Department of Health the suicides rates have been decreasing. Since the year 2000 until December 2023 a total of 6,891 suicides across the archipelago. The annual average is 287 suicides and a rate of 7.9 per 100,000 inhabitants.

*Table 1*

| SUICIDE RATE IN PUERTO RICO | | | | |
|---|---|---|---|---|
| YEAR | POPULATION | SUICIDES | CRUDE RATE PER 100,000 INHABITANTS | AGE-ADJUSTED RATE PER 100,000 INHABITANS |
| 2017 | 3,325,286 | 302 | 9.1 | 7.8 |
| 2018 | 3,193,354 | 272 | 8.5 | 7.8 |
| 2019 | 3,193,694 | 234 | 7.3 | 6.6 |
| 2020 | 3,281,557 | 208 | 6.3 | 5.8 |
| 2021 | 3,262,693 | 214 | 6.6 | - |
| 2022 | 3,221,789 | 177 | 5.5 | - |
| 2023 | 3,205,691 | 201 | 6.3 | - |

*Note. Data from the Institute of Forensic Sciences of Puerto Rico. Preliminary data as December 31, 2023.*

# AFFECTED SYSTEMS AND SOCIAL DETERMINANTS OF HEALTH CONFERRING HEALTH DISPARITIES

Social determinants of health (SDoH) are nonmedical factors that affect health outcomes. According to the World Health Organization (WHO), they encompass the conditions into which individuals are born, grow, work, live, and age, along with the broader forces and systems that shape these everyday circumstances. These influencing factors include economic policies, development agendas, social norms, political systems, and social policies (WHO, 2019)

Residents of Puerto Rico frequently face numerous challenges impacting public health, such as poverty, an under-resourced healthcare system, inadequate infrastructure, economic struggles, and vulnerability to climate change (Lafarga Previdi & Vélez Vega, 2020). These challenges have worsened after hurricane Maria in 2017, multiple earthquakes since 2019 and COVID-19 pandemic (García, Rivera, Garcia, Burgos, & Aranda, 2021). Climate change is one of the public health threats of our time, which similarly to the other SDoH, worsens health, increases health care costs, disproportionately impacts vulnerable communities and exacerbates the effects of other SDOHs (Ragavan, Marcil, & Garg, n.d.).

In our archipelago, a portion of the population faces heightened risks from the impacts of climate change, including people that depend on electricity for survival. The energy system in Puerto Rico is vulnerable to climate change impacts, such as rising temperatures, heat waves and hurricanes. While these impacts may differ from one area to another, they will continue to affect the archipelago. Many individuals in our population depend on electricity-powered medical equipment and other devices that enable them to live independently at home (Environmental Protection Agency, 2024). The US Department of Health interactive map (HHS emPOWER Map) displays the total number of Medicare beneficiaries who had an administrative claim for one or more types of electricity-dependent durable medical and assistive equipment and devices. Also, it includes at-risk combinations data for those who rely on a certain essential health care service(s). In Puerto Rico there is a total of 760,870 beneficiaries of Medicare (HHS EmPOWER Map, 2024).

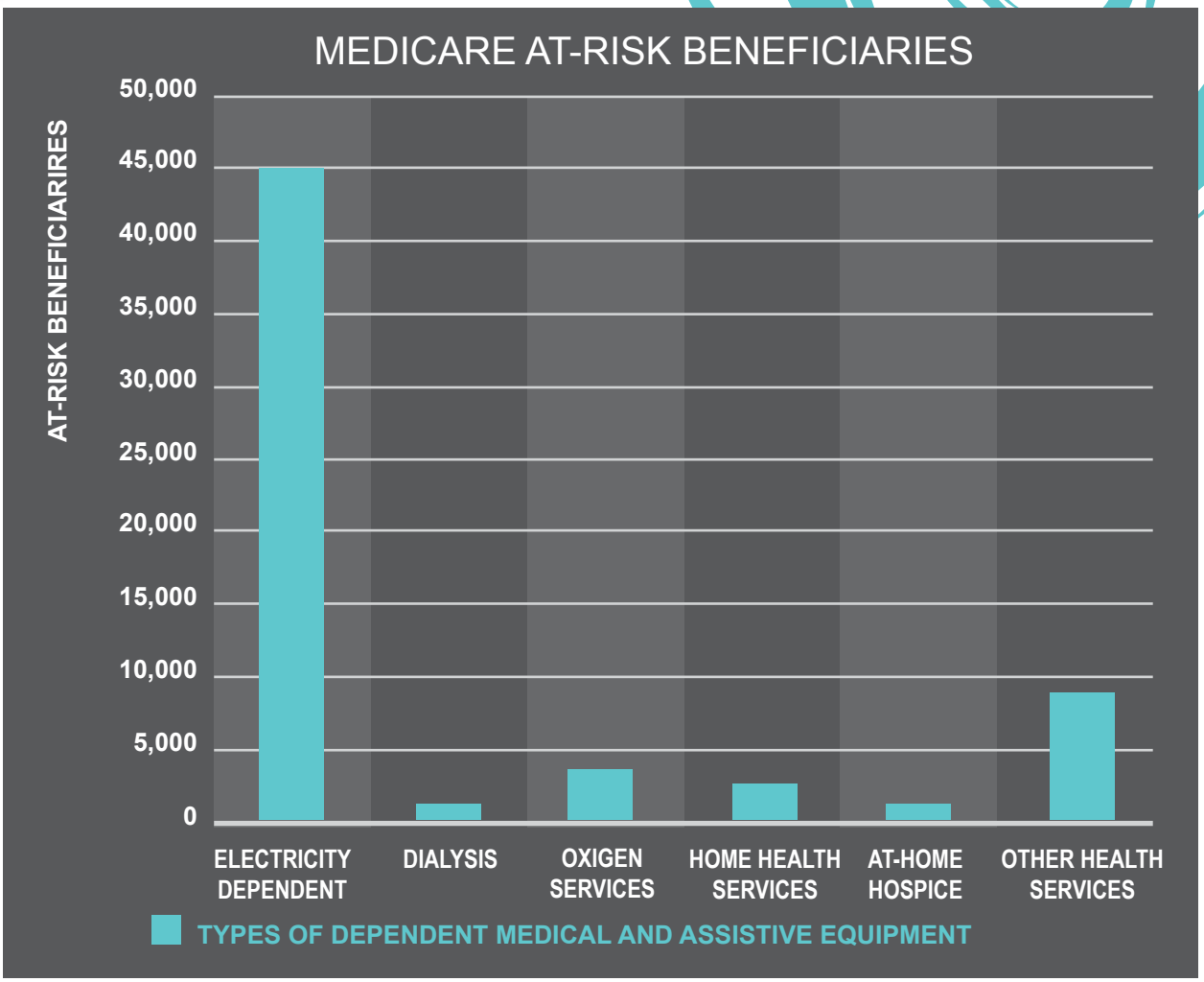



*Figure 2: Medicare At-Risk Beneficiaries Who Rely on Electricity-Dependent Durable Medical and Assistive Equipment (DME)*

*Source: US Department of Health and Human Services29*

# ADAPTIVE CAPACITY FOR CLIMATE CHANGE IN PUERTO RICO

The Puerto Rico Coastal Zone Management Program (PRCZMP), under the Puerto Rico Department of Natural and Environmental Resources (PRDNER), oversees the Puerto Rico Climate Change Council (PRCCC). In 2013, the PRCCC published Puerto Rico's State of the Climate 2010-2013, assessing socio-economic vulnerabilities related to climate change. That same year, the Governor issued Executive Order OE-2013-016, requiring government agencies to assess the vulnerability of their public infrastructure to climate change, including sea level rise, and to develop adaptation measures. These measures were to be incorporated into technical guidelines for infrastructure maintenance, repair, and new projects. The PRDNER was designated as the lead agency to compile, review, and report the vulnerability assessments and adaptation plans from each agency (PRDNER, 2015).

In 2019, the Puerto Rico Climate Change Mitigation, Adaptation, and Resilience Act (Ley 33) established public policy on climate change, focusing on mitigation, adaptation, and resilience across sectors. The Act created a greenhouse gas inventory, set emission reduction targets, and required sector-specific climate adaptation plans. It also established the Expert Advisory Committee on Climate Change, integrated climate change into school curricula, and amended laws to promote renewable energy, waste reduction, and energy efficiency.

The Expert Advisory Committee on Climate Change (CEACC) was established under Law 33-2019, the "Puerto Rico Climate Change Mitigation, Adaptation, and Resilience Act." The Committee's primary responsibility is to develop a comprehensive Climate Change Mitigation, Adaptation, and Resilience Plan for Puerto Rico.

In April 2024, Puerto Rico released the latest draft of its Climate Change Mitigation, Adaptation, and Resilience Plan (P-MARCC), which aligns with the strategic framework and emission reduction goals set forth in Law 33 of 2019. This plan outlines the successful development of a comprehensive structure for climate change mitigation and adaptation, providing sector-specific assessments based on scientific data. The plan includes the identification of critical action areas to address greenhouse gas emissions, transition to renewable energy, and update public infrastructure, including the vehicle fleet. It also establishes clear strategies to reduce energy demand and promote reforestation efforts. The final draft reflects the comprehensive integration of these measures, supported by a series of action plans and timelines to ensure Puerto Rico's resilience in the face of climate change.

The P-MARCC aims to create targeted protection strategies for the most vulnerable population groups across different health regions in Puerto Rico. It emphasizes the need to address all climate-related events and their impacts on public health, including extreme heat, droughts, sea level rise, storms, and floods. The plan also focuses on mitigating issues related to air and water quality and food safety.

Additionally, the P-MARCC proposes a curricular change in education, integrating climate change as a key theme across all academic grades from kindergarten to twelfth grade. This curricular review aims to involve both public and private schools, providing concrete examples of climate change impacts specific to Puerto Rico. The objective is to help students understand the relevance of climate change and how to prepare for its effects in both the short and long term. The development of this curriculum will be conducted in consultation with climate change experts and will incorporate relevant indicators as outlined in the draft plan.

**1st Adaptative action by CAPBRACE: Disaster Planning for Impacts from Climate Change**

The initiative aims to enhance community resilience against climate-related health risks in Torrecilla Baja (Piñones), Loíza, Puerto Rico.

1. **Assessment:** A thorough evaluation of extreme heat, drought, sea level rise, storms, floods, air quality, water quality, and food safety will be conducted to assess their impact on public health and recommend adaptive measures.

2. **Community Emergency Plan:** Collaboration with local residents and experts will lead to the development of a comprehensive community emergency plan that addresses pre-emergency preparedness and implementation strategies.

3. **Disaster Preparedness Engagement:** Community members will be engaged in disaster preparedness efforts, focusing on essential items to manage extreme heat, such as thermometers, battery-operated fans, solar chargers, and instant ice packs.

4. **Emergency Planning Workbook:** Facilitating the completion of an emergency planning workbook will empower residents with knowledge and skills to effectively respond to emergencies, fostering a well-informed and prepared community.

**2nd Adaptative action by CAPBRACE: Educational Curriculum on How to Mitigate Human Health Impacts from Climate Change**

This action aims to educate the younger generation about the health impacts of climate change and promote proactive measures.

1. **Adapt existing climate-health** curriculum for secundary level students, focusing on the impacts of climate change and the health benefits of mitigation strategies. The curriculum will be based on evidence from the National Institutes of Health, National Climate Assessment and the American Public Health Association Toolkit.

**PROMOTING HEALTHY LEARNING ENVIRONMENTS**

According to the CDC (2024), a healthy school is one that promotes the health and safety of students, helping them establish lifelong health patterns. Schools are an ideal setting to teach and provide students with opportunities to improve their dietary and physical activity behaviors, manage chronic health conditions, and develop healthy habits and health literacy. A supportive school environment helps children and adolescents develop the skills they need to recognize and manage emotions, set and achieve positive goals, appreciate the perspectives of others, establish and maintain positive relationships, and make responsible decisions. This aligns with the Whole School, Whole Community, Whole Child (WSCC) framework, which is CDC approach to addressing health in schools. The WSCC framework emphasizes the role of the community in supporting the school, the connections between health and academic achievement, and the importance of evidence-based school policies and practices.

The Fifth National Climate Assessment highlights the significant vulnerabilities and impacts of climate change on Puerto Rico and the broader Caribbean region. It emphasizes that traditionally underserved and disadvantaged communities suffer disproportionately from climate-related extreme events due to systematic exclusion from social services, quality education, and other benefits that support health and well-being. The report underscores that effective adaptation to support resilience in the region could be enhanced through decentralization, shared governance, and stronger partnerships between the Caribbean and the U.S. mainland. As extreme weather events become more intense and frequent, the health and well-being of residents are increasingly at risk, with higher rates of disease, mental illness, and overall mortality expected. Addressing these challenges requires comprehensive strategies that integrate community support and evidence-based policies to mitigate the adverse effects of climate change (Fifth National Climate Assessment, 2023).

The Puerto Rico Department of Education (PRDE) has not specifically mentioned or incorporated the concept of "healthy learning environments" in its official initiatives or documentation. While the PRDE has launched various efforts to improve educational outcomes, such as the Initiative for Decentralization of Education and Autonomy of Regions (IDEAR), these initiatives primarily focus on decentralization, financial management, and academic management (U.S. Department of Education, 2024). However, within the official website of the Puerto Rico Department of Education, strategies for preventing incidents due to extreme heat episodes in primary and secondary schools are outlined. The actions for preparedness and prevention of heat-related incidents are the responsibility of the regional superintendents, the team at the regional education office, and school principals. These actions include three main elements:

- **School Environment:** Ensuring proper ventilation, access to water, and shaded areas for students and staff.

- **Routines and Protocols:** This includes modified uniforms and a flexible dress code for school employees, adjustments to the school schedule, and the implementation of regular breaks for hydration and cooling.

- **Communication and Training:** Establishing protocols for responding to extreme heat emergencies, training school personnel, communicating with families, and disseminating information and signage in affected areas.

- Despite these plans, in January 2025, the President of the Puerto Rico Teachers Association publicly denounced that the government has failed to execute a comprehensive plan to address heat waves in schools.

- To enhance educational outcomes, the PRDE could consider integrating strategies that focus on student and teachers' well-being, such as fostering healthy learning environments.

# REFERENCES


Abdullah, N.A.M.H., Dom, N.C., Salleh, S.A., Salim, H., & Precha, N. (2022). The association between dengue case and climate: A systematic review and meta-analysis. One Health, 15, 100452. ***https://doi.org/10.1016/j.onehlt.2022.100452***

Agency for Toxic Substances and Disease Registry. (2022, November 3). CDC/ATSDR Social Vulnerability Index (SVI) | Place and Health | ATSDR. Atsdrdev.cdc.gov. ***https://www.atsdr.cdc.gov/placeandhealth/svi/interactive_map.html***

Briskin, E.A., Casanovas-Massana, A., Ryff, K.R., Morales-Estrada, S., Hamond, C., Perez-Rodriguez, N.M., Benavidez, K.M., Weinberger, D.M., Castro-Arellano, I., Wunder, E.A., Sharp, T.M., Rivera-Garcia, B., & Ko, A.I. (2019). Seroprevalence, Risk Factors, and Rodent Reservoirs of Leptospirosis in an Urban Community of Puerto Rico, 2015. The Journal of Infectious Diseases, 220(9), 1489–1497. ***https://doi.org/10.1093/infdis/jiz339***

Calo WA, Rivera M, Mendez-Lazaro PA, et al. Disruptions in Oncology Care Confronted by Patients with Gynecologic Cancer Following Hurricanes Irma and Maria in Puerto Rico. Cancer Control. 2022;29. doi:10.1177/10732748221114691

Centers for Disease Control and Prevention. (2024). Chikungunya Virus. Symptoms, Diagnosis, & Treatment | Chikungunya Virus | CDC.

Centers for Disease Control and Prevention. (2024). How dengue spreads. Dengue. ***https://www.cdc.gov/dengue/transmission/index.html***

Centers for Disease Control and Prevention. (2024). Whole School, Whole Community, Whole Child (WSCC). Retrieved ***from https://www.cdc.gov/whole-school-community-child/about/index.html***

Cruz, M.A., Garfield, R., Irizarry, J., Torres-Delgado, N.I., Rodriguez-Rivera, M.Z., Montoya-Zavala, M., Maas Cortes, L., Algarín, G., Bayleyegn, T., Funk, R.H., Rodriguez-Orengo, J.F., & Zavala, D.E. (2023). Assessing the living environment of persons displaced following a strong earthquake sequence in Puerto Rico, 2020. Journal of Emergency Management, 21(6), 487–500.

Collins, J., Polen, A., Dunn, E., Maas, L., Ackerson, E., Valmond, J., & Colón-Burgos, D. (2022). Hurricane hazards, evacuations, and sheltering evacuation decision-making in the prevaccine era of the COVID-19 pandemic in the PRVI region. Weather, Climate, and Society, 14(2), 451-466.

Daniel Tong, Alexander A. Baklanov, Bridget Marie Barker, Juan J Castillo-Lugo, Santiago Gassó, Cassandra J. Gaston, Thomas E. Gill, Dale Warren Griffin, Nicolas Huneeus, Ralph A. Kahn, Arunas P Kuciauskas, Luis A. Ladino, Junran Li, Olga L. Mayol-Bracero, Orion McCotter, Pablo Andres Méndez-Lázaro, Pierpaolo Mudu, Slobodan Nickovic, Damian Oyarzun, Joseph M. Prospero, Graciela B Raga, Amit U Raysoni, Ling Ren, Nikias Sarafoglou, Andrea Sealy, William Sprigg, Ziheng Sun, Robert Scott Van Pelt, Ana Vukovic Vimic. 2021. Health and Safety Effects of Airborne Soil Dust in the Americas and Beyond. AGU journal submission 2021RG000763Di

De Ángel Solá D., Wang L., Vázquez, M., Méndez Lázaro, P. Weathering the pandemic: How the Caribbean Basin can use viral and environmental patterns to predict, prepare and respond to COVID-19. 2020. Journal of Medical Virology. DOI:10.1002/jmv.25864

de Jesús Crespo, R., Méndez-Lázaro, P. and Yee, S.H. 2018. Linking Wetland Ecosystem Services to Vector-borne Disease: Dengue Fever in the San Juan Bay Estuary, Puerto Rico. Wetlands (2018). ***https://doi.org/10.1007/s13157-017-0990-5***

Eckstein, D., Künzel, V., & Schäfer, L. (2021). Global Climate Risk Index 2021: Who suffers most from extreme weather events? Weather-related loss events in 2019 and 2000 to 2019. Germanwatch e.V. ***https://www.germanwatch.org/en/19777***

Filho, W.L., Scheday, S., Boenecke, J., Gogoi, A., Maharaj, A., & Korovou, S. (2019). Climate Change, Health and Mosquito-Borne Diseases: Trends and Implications to the Pacific Region. Int J Environ Res Public Health, 16(24), 5114. https://doi.org/10.3390/ijerph16245114

García, C., Rivera, F.I., Garcia, M.A., Burgos, G., & Aranda, M.P. (2021). Contextualizing the COVID-19 era in Puerto Rico: compounding Disasters and parallel pandemics. J Gerontol B Psychol Sci Soc Sci, 76(7), e263–7. https://doi.org/10.1093/geronb/gbaa186.

Gould, W.A., E.L. Díaz, (co-leads), N.L. Álvarez-Berríos, F. Aponte-González, W. Archibald, J.H. Bowden, L. Carrubba, W. Crespo, S.J. Fain, G. González, A. Goulbourne, E. Harmsen, E. Holupchinski, A.H. Khalyani, J. Kossin, A.J. Leinberger, V.I. Marrero-Santiago, O. Martínez-Sánchez, K. McGinley, P. Méndez-Lázaro, J. Morell, M.M. Oyola, I.K. Parés-Ramos, R. Pulwarty, W.V. Sweet, A. Terando, and S. Torres-González, 2018: U.S. Caribbean. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. xx–xx. doi: 10.7930/NCA4.2018.CH20

Hartnett, J.J., Dunn, E.A., Collins, J.M., Maas Cortes, L., & Jones, R. (2023). Evacuation decision-making post-COVID-19 vaccine availability: Implications of compound hazards in Puerto Rico and the U.S. Virgin Islands. Weather, Climate, and Society. Manuscript submitted for publication, October 2023.

Holladay, Patrick J.; Méndez-Lázaro, P. and Brundiers, Katja (2021). From hurricanes to pandemics: community-based transformation and destination resilience in Utuado, Puerto Rico. Journal of Sustainability and Resilience, Volume 1, Issue 2, Pages 1-6transformation and destination resilience in Utuado, Puerto Rico

How to protect vulnerable groups from extreme heat. (2019). Natural disasters and severe weather. CDC. ***https://www.cdc.gov/es/disasters/extremeheat/specificgroups.html***

J. Norat-Ramírez, P. Méndez-Lázaro, E.A. Hernández-Delgado, H. Mattei-Torres, L. Cordero-Rivera. A septic waste index model to measure the impact of septic tanks on coastal water quality and coral reef communities in Rincon, Puerto Rico. Ocean & Coastal Management. Volume 169, 2019, Pages 201-213. ISSN 0964-5691, https://doi.org/10.1016/j.ocecoaman.2018.12.016

Johnson M, Parada H Jr, Ferran K, Perez R, Calo W, Sant'Ana IDL, Ocasio LM, Mendez-Lazaro PA, Garcia SI, Tortolero-Luna G, Umpierre SA, Ortiz AP. Perceptions of preparedness, timing of cancer diagnosis, and objective emergency preparedness among gynecological cancer patients in Puerto Rico before and after Hurricane Maria. J Cancer Policy. 2023 Jun;36:100415. doi: 10.1016/j.jcpo.2023.100415. Epub 2023 Feb 23. PMID: 36828176.

Lafarga Previdi, I., & Vélez Vega, C.M. (2020). Health Disparities Research Framework Adaptation to reflect Puerto Rico's Socio-Cultural Context. Int J Environ Res Public Health, 17(22), 8544. ***https://doi.org/10.3390/ijerph17228544.***

Laureano-Rosario, A.E.; Duncan, A.P.; Mendez-Lazaro, P.A.; Garcia-Rejon, J.E.; Gomez-Carro, S.; Farfan-Ale, J.; Savic, D.A.; Muller-Karger, F.E. Application of Artificial Neural Networks for Dengue Fever Outbreak Predictions in the Northwest Coast of Yucatan, Mexico and San Juan, Puerto Rico. Trop. Med. Infect. Dis. 2018, 3, 5.

Leptospirosis. (2024, June 24). Centers for Disease Control and Prevention. Retrieved August 28, 2024, from ***https://www.cdc.gov/leptospirosis/about/index.html***

Marvell, P., & Marvell, P. (2024, January 23). Climate change stresses physical and mental health in Puerto Rico and U.S. Virgin Islands. Yale Climate Connections. ***https://yaleclimateconnections.org/2024/01/climate-change-stresses-physical-and-mental-health-in-puerto-rico-and-u-s-virgin-islands/***

McPhillips L.E., H. Chang, M.V. Chester, Y. Depietri, E. Friedman, N.B. Grimm, J.S. Kominoski, T. McPhearson, P. Méndez-Lázaro, E.J. Rosi, J. Shafiei Shiva. 2018. Defining extreme events: a cross-disciplinary review. Earth's Future. DOI: 10.1002/2017EF000686

Méndez-Lázaro, P., Chardón-Maldonado, P., Carrubba, L., Álvarez-Berríos, N., Barreto, M., Bowden, J.H., Crespo-Acevedo, W.I., Diaz, E.L., Gardner, L.S., Gonzalez, G., Guannel, G., Guido, Z., Harmsen, E.W., Leinberger, A.J., McGinley, K., Ortiz, A.P., Pulwarty, R.S., Ragster, L.E., Rivera-Collazo, I.C., Santiago, R., Santos-Burgoa, C., & Vila-Biaggi, I.M. (2023). Ch. 23. US Caribbean. In: Fifth National Climate Assessment (A.R. Crimmins, C.W. Avery, D.R. Easterling, K.E. Kunkel, B.C. Stewart, & T.K. Maycock, Eds.). U.S. Global Change Research Program, Washington, DC, USA. ***https://doi.org/10.7930/NCA5.2023.CH23.***

Méndez-Lázaro, P.A., Bernhardt, Y.M., Calo, W.A., Pacheco Díaz, A.M., García-Camacho, S.I., Rivera-Lugo, M., Acosta-Pérez, E., Pérez, N., & Ortiz-Martínez, A.P. (2021). Environmental stressors suffered by women with gynecological cancers in the aftermath of Hurricanes Irma and María in Puerto Rico. Int J Environ Res Public Health, 18(21), 11183. doi: 10.3390/ijerph182111183. PMID: 34769708; PMCID: PMC8583450.

Méndez-Lázaro, P.A., Bernhardt-Utz, Y.M., Calo, W.A., Pacheco Díaz, A.M., García-Camacho, S.I., Rivera-Lugo, M., Acosta-Pérez, E., Pérez, N., & Ortiz-Martínez, A.P. (2021). Environmental stressors suffered by women with gynecological cancers in the aftermath of Hurricanes Irma and Maria in Puerto Rico. Submitted (July 23, 2021): International Journal of Environmental Research and Public Health.

Méndez-Lázaro, P., Muller-Karger, F.E., Otis, D., McCarthy, M., & Peña-Orellana, M. (2014). Assessing Climate Change effects on dengue incidence in San Juan, Puerto Rico. Int. J. Environ. Res. Public Health, 11(9), 9409-9428. doi:10.3390/ijerph110909409.

Méndez-Lázaro, P., Muller-Karger, F.E., Otis, D., McCarthy, M., & Rodríguez, E. (2017). A Heat Vulnerability Index to Improve Urban Public Health Management in San Juan, Puerto Rico. International Journal of Biometeorology. doi:10.1007/s00484-017-1319-z.

Méndez-Lázaro, P.A., Pérez-Cardona, C.M., Rodríguez, E., Martínez-Sánchez, O., Taboas, M., Bocanegra, A., & Méndez-Tejeda, R. (2016). Climate change, heat, and mortality in the tropical urban area of San Juan, Puerto Rico. International Journal of Biometeorology. doi:10.1007/s00484-016-1291-z.

Napoli, C., Allen, T., Méndez-Lázaro PA, Pappenberge, F. Heat stress in the Caribbean: climatology, drivers, and trends. JOC-21-0775 International Journal of Climatology Confirmation of Submission. (September 14, 2021).

National Center for Health Statistics. (2017). A reference guide for certification of deaths in the event of a natural, human-induced, or chemical/radiological disaster. Hyattsville, MD.

Non-communicable Diseases - UNICEF Data. (n.d.). ***https://data.unicef.org/topic/child-health/noncommunicable-diseases/***

Ortíz, A.P., Méndez-Lázaro, P., Calo, W.A., García-Camacho, S., Tortolero-Luna, G. Strengthening resilience and adaptive capacity to natural disasters in cancer control plans: Lessons learned from Puerto Rico. 2020. Cancer Epidemiology, Biomarkers & Prevention. (DOI: 10.1158/1055-9965.EPI-19-1067).

Pan American Health Organization/World Health Organization Strategic Plan of Action for the Prevention and Control of Non-communicable Diseases for Countries of the Caribbean Community 2011-2015. [Accessed 21 February 2018]. Available from: ***https://caricom.org/documents/12630-ncds_plan_of_action_2011_2015.pdf***

Pascual, O.S. (2017, December 7). Nearly 1,000 more people died in Puerto Rico after Hurricane María. Centro de Periodismo Investigativo. ***http://periodismoinvestigativo.com/2017/12/nearly-1000-more-people-died-in-puerto-rico-after-hurricane-maria/***

Patrick J. Holladay, Pablo Mendez-Lazaro, Heriberto Marin Centeno, Ralph Rivera-Gutierrez, Keenan Adams and Katja Brundiers. 2019. Utuado, Puerto Rico and Community Resilience Post-Hurricane Maria: The Case of Tetuan Reborn. Recreation, Parks, and Tourism in Public Health , Vol. 3 (2019), pp. 5-16 Published by: Indiana University Press Stable URL: ***https://www.jstor.org/stable/10.2979/rptph.3.1.02***

Puerto Rico Department of Health. (2024). Vigilancia Enfermedades Arbovirales. ***https://www.salud.pr.gov/CMS/DOWNLOAD/9248***

Puerto Rico Department of Health. (2024, October 15). Informe Semanal Enfermedades Arbovirales. ***www.salud.gov.pr. https://www.salud.pr.gov/CMS/365***

Puerto Rico Department of Health. (2024). Informe mensual de la Vigilancia de Leptospirosis. San Juan, PR. Vigilancia de Leptospirosis, División de Epidemiología e Investigación.

Puerto Rico. (n.d.). Platform.who.int. ***https://platform.who.int/mortality/countries/country-details/MDB/puerto-rico***

Quick facts: Hurricane Maria's effect on Puerto Rico. (2018, January 19). ReliefWeb. ***https://reliefweb.int/report/puerto-rico-united-states-america/quick-facts-hurricane-marias-effect-puerto-rico***

Ragavan, M.I., Marcil, L.E., & Garg, A. (2024). Climate Change as a Social Determinant of Health | Pediatrics | American Academy of Pediatrics (aap.org)

Ryan, S., et al. (2020). Warming temperatures could expose more than 1.3 billion new people to Zika virus risk by 2050. Global Change Biology. ***https://doi.org/10.1111/gcb.15384***

Sanders, E.J., Rigau-Pérez, J.G., Smits, H.L., et al. (1999). Increase of leptospirosis in dengue-negative patients after a hurricane in Puerto Rico in 1996 [correction of 1966]. Am J Trop Med Hyg, 61, 399–404.

Stanaway, J.D., Shepard, D.S., Undurraga, E.A., Halasa, Y.A., Coffeng, L.E., Brady, O.J., et al. (2016). The global burden of dengue: an analysis from the Global Burden of Disease Study 2013. Lancet Infect. Dis., 16, 712–723. https://doi.org/10.1016/S1473-3099(16)00026-8

U.S. Census Bureau. (2020). QuickFacts: Puerto Rico. U.S. Department of Commerce. U.S. Census Bureau QuickFacts: Puerto Rico.

U.S. Census Bureau. (n.d.). Risk factors for Puerto Rico. Retrieved October 29, 2024, from ***https://mtgisportal.geo.census.gov/arcgis/apps/experiencebuilder/experience/?data_id=dataSource_12-CRE_for_Puerto_Rico_6247-8%3A99&id=e851575739ca4b4281037d92cc62cbd4&page=3%2B-Risk-Factors***

U.S. Department of Education. (2024). Puerto Rico's Education System Transformation. Retrieved ***from https://www.ed.gov/laws-and-policy/education-policy/puerto-ricos-education-system-transformation***

U.S. Global Change Research Program. (2023). Fifth national climate assessment (A.R. Crimmins, C.W. Avery, D.R. Easterling, K.E. Kunkel, B.C. Stewart, & T.K. Maycock, Eds.). Washington, DC: U.S. Global Change Research Program. https://doi.org/10.7930/NCA5.2023

Uncovering Hurricane Maria's true toll. (2019). News. ***https://www.hsph.harvard.edu/news/features/hurricane-maria-deaths***

WCAS-D-23-0007, "Who Is Affected by Saharan Dust in the Caribbean? A Spatial Analysis and Citizen's Perspective from Puerto Rico during the Godzilla Dust Event in June 2020

World Health Organization. (2019, May 30). Social determinants of health

World Health Organization. (2023, November 2). Climate Change and Noncommunicable diseases: Connections. ***Www.who.int. https://www.who.int/news/item/02-11-2023-climate-change-and-noncommunicable-diseases-connections***

# NOTES

# NOTES


Puerto Rico
Public Health Trust
A program of:
Puerto Rico
Science, Technology
& Research Trust


CDC
U.S. CENTERS FOR DISEASE
CONTROL AND PREVENTION