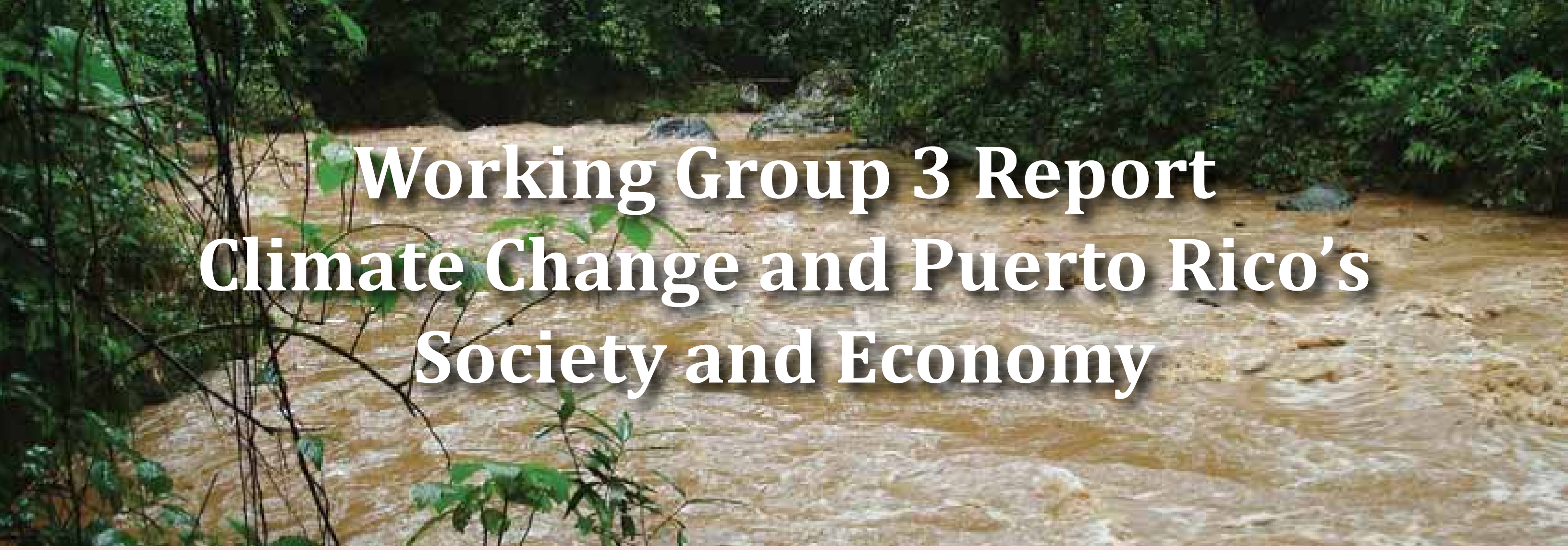


Working Group 3 Report Climate Change and Puerto Rico's Society and Economy

Editors:

Kasey R. Jacobs[1] and Ernesto L. Diaz[1]

Contributing Authors (In Alphabetical Order):

Lisamarie Carrubba[2], Juan A. Castañer[3], Ruperto Chaparro[4], Wanda L. Crespo Acevedo[3], Ernesto Diaz[1], Raimundo Espinoza[5], Soledad Gaztambide[6], Kasey R. Jacobs[1], Roberto Moyano[3], Víctor Nieto[8], Susan Pacheco[10,11], Antares Ramos[9], Pedro Santa[8], Raúl Santiago Bartolomei[3], Raul Santini Rivera[1], Jose Seguinot Barbosa[12], Jose Juan Terrasa[13]

Acknowledgments:

This report is a product of the project *Puerto Rico Coastal Adaptation Project* carried out by the Puerto Rico Coastal Zone Management Program and funded by NOAA's OCRM through Section 309 of the Coastal Zone Management Act. A special thanks to EPA, DNER, NOAA, USFWS, USGS, and IITF for sponsoring the November 2011 conference *Climate Change in the Caribbean: Puerto Rico and the U.S. Virgin Islands* where many key discussions occurred as well as the Puerto Rico Tourism Company, the Puerto Rico Conservation Trust and The Nature Conservancy for their support of conference activities and throughout the development of this report. We would like to thank you Carla Loubriel for assistance with editing earlier versions of the report. We also thank the Social and Environmental Research Institute, the South Carolina Sea Grant Consortium, and the University of South Carolina for their development and training of the VCAPS diagrams and process that was used to facilitate WG 3 meeting discussions and the writing process.g process.

[1]Puerto Rico Coastal Zone Management Program at the Department of Natural and Environmental Resources
[2] NOAA Marine Fisheries Service
[3]Estudios Técnicos, Inc.
[4]Puerto Rico Sea Grant College Program
[5]The Nature Conservancy
[6]The Conservation Trust of Puerto Rico
[7]University of Puerto Rico School of Architecture
[8]AA.E.I.O.U
[9]NOAA Ocean and Coastal Resource Management
[10] The Climate Reality Project – Puerto Rico
[11]University of Texas
[12] University of Puerto Rico Medical Sciences Campus
[13]The Puerto Rico Tourism Company, Division of Planning

TABLE OF CONTENTS

Overview of Puerto Rico's Existing Vulnerabilities

The Commonwealth of Puerto Rico consists of 78 municipalities; 44 are coastal or insular. As of April 1, 2010 Puerto Rico's population was 3,725,789, or 82,821 less than in April 2000. This is the first time since the Federal Census has been conducted in Puerto Rico that the Puerto Rican population decreased from one decade to another. The analysis conducted by the Puerto Rico Coastal Zone Management Program using the 2010 Census data shows that 56% of the population (2,317,189 people) live in the coastal municipalities. Puerto Rico has an area of 9,497 km^2 (3,508 mi^2) and a population density of almost 449 inhabitants per km^2 (449 inhabitants per ~0.4mi^2). According to the United Nations Demographic Yearbook, this represents one of the highest population densities in the World. Average life expectancy is 78.5 years and 94.1% of the population is literate; Puerto Rico would rank high in terms of the United Nation's Human Development Index. However, there are other relevant socioeconomic conditions that may affect Puerto Rico's capacity to cope and adapt to potential non-climate and climate stressors.

Puerto Rico's population reflects high levels of vulnerability to hazards. The most vulnerable are those who are economically disadvantaged, less prepared, and under social inequitable conditions, such as insufficient infrastructure and services. Puerto Rico has a growing elderly population. In 2010, 15% of the population was 65 years or more, versus 11.2% reported in 2000. According to the 2010 Census, 56.3% of the population lives below the poverty line. Per capita income in 2010 was $10,392, significantly lower than the $26,059 reported for the mainland United States. The highest educational level attained by 57% of the population ranges from not having completed a degree to a high school diploma. Data from the Puerto Rico Department of Labor and Human Resources reveals that unemployment occurs amongst people with all levels of education, especially among those employees who does not have a high school diploma, but also among those with an Associate's Degree; while the unemployment rates for those with a college education or a higher degree are lower than the Puerto Rico average. And there are fewer people in the labor force. The percentage of the working age population employed or looking for a job has fallen slightly but remains high. In 2005 the

- **56% of the population lives in coastal municipalities**
- **52% of population are female**
- **25% of the population are under 18 years of age**
- **Unemployment rate: 14.9% (as of March 2012)**
- **56.3% of the population lives below the poverty line**
- **Median household income: $18,692**
- **Per capita income: $10,392 (2010).**
- **94.1% of the population is literate**

[1] United Nations, Department of Economics and Social Affairs, United Nations Statistic Division. Demographic Year Book. (Table No.3, Population by sex, annual rate of population increase, surface area and density). Retrieved from http://unstats.un.org/unsd/demographic/products/dyb/dyb2009-2010.htm.

[2] Department of Labor and Human Resources. Educational Level of the Labor Force in Puerto Rico.

employment rate was 47.7% and in 2011 it fell to 40.5%. This suggests that an increasing number of people have left the formal employment market.

According to the U.S. Census the majority of the population lives in urban areas. This is a significant change from the period 1900 to 1930, when almost 80% of the island's population was rural (U.S. Census Bureau, 1900-1930, 2000). Today, more than half of the population lives in the San Juan Metropolitan Area. The metropolitan municipalities, like San Juan and Carolina, are where activities and services are concentrated: Puerto Rico's main seaport and airport; the most important healthcare center of Puerto Rico and the Caribbean (Centro Médico) and the major universities. Government services are also highly concentrated in San Juan. The coastal zone of the San Juan Metropolitan Area as well as other coastal areas is where most hotels, essential infrastructure, and electric power plants are located. In fact, some power plants are less than 160 feet from the waterline and less than six feet above sea level. Most businesses and other forms of economic activity are located in the coastal zone as well.

The rapid urbanization of the Commonwealth that occurred during past decades has drastically covered Puerto Rico's watersheds with impervious surfaces. Impervious surfaces like asphalt, cement and roofing prevent infiltration of rainfall into the soil, disrupting the water cycle and affecting both the quantity and quality of our water resources. As a result, there are thousands of people living in flood-prone areas. As of 2010, it was estimated than 237,050 people live in floodways; subject to material damages and potential losses of life.

The increased amount of impervious surfaces and resulting flooding has also contributed to outbreaks of the dengue virus as communities struggle with eliminating breeding sites of the predominant mosquito vector, *Aedes aegypti* . In fact, Puerto Rico experienced the largest dengue virus outbreaak in its history in 2010, recording over 21,000 reported cases. About 75% of the reported cases could be laboratory confirmed and, because mild cases are often not reported, the incidence was probably at least several times higher.

In addition to floodways, 105,116 people live in areas subject to storm surges, which are extreme increases in sea level caused by tropical cyclone paths. In Puerto Rico, the southern and eastern coasts are most vulnerable to the impact of storm surges due to its shallow coastline and hurricane trajectories. Seven months after Hurricane Irene struck Puerto Rico in August 2011, the island was continuing to recover from the heavy rains, flooding, landslides and mudslides left by the

[3] Center for Sustainable Development Studies. (2009). Sustainability of Land Use in Puerto Rico.

[4] Estimates were calculated combining GIS layers of 2010 US Census Bureau and FEMA Flood Insurance Rate Maps (AE Floodway) as of 2009.

[5] AE floodway is defined as a "special flood hazard area with a recurrence period of 100 years, determined by specific methods and for which the elevations of the base flood is indicated. According to the extent of the study, it may include the determination of the floodway. According to the Puerto Rico Planning Board, Regulation on Special Flood Hazard Areas or Planning Regulation No. 13, this area must remain free of obstructions to allow the downward flow of flood waters. The placement of filling material and/or the construction of buildings on it may obstruct the free flow of the waters and increase flood levels.

[6] One Puerto Rico-specific study demonstrated that increased temperature and rainfall are associated with increased dengue transmission in subsequent months across Puerto Rico. The study also demonstrated that differences in local climate within Puerto Rico can explain local differences observed in the relationship between weather and dengue transmission (Johansson et al. 2009).

hurricane. The Government of Puerto Rico and the Federal Emergency Management Agency cited the approval of more than $83.9 million in federal grants for disaster aid (FEMA 2012). Effects can be long-lasting, such as with the diminishment of the coffee and plantain industries on the island after two strong hurricanes in 1928 and 1932 or the long lasting impacts to agriculture and infrastructure after hurricanes Hugo (1989) and Georges (1998). After hurricane Georges the National Weather Service reported enormous damage to Puerto Rico's utility infrastructure. Electricity was lost to 96% of the island 1.3 million customers, while water and sewer service was lost to 75% of the islands 1.83 million customers. It was estimated that at least 50% of the electrical poles and cables were damaged. Many roads were impassable by floods or destruction. A large number of road signs were twisted and destroyed, while electric post and cables were strewn on the ground, along with trees and foliage. Damage to roads was estimated at $21,995,975. More than 217,000 homes were damages and over 29,000 people were left homeless. Telephone service was also affected as 8.4% of telephone customers lost their service. Hurricane Georges' extensive damages to the agricultural sector including losses of 75% of the island's coffee crop, 95% of the plantain and banana crops, and 65% of its live poultry. Loss to equipment, manufacturing, and agriculture was estimated at $212.9 million daily. Damage to houses was significant, especially those constructed of wood with wood-zinc system roofs. In all 28,005 house were totally destroyed and 72, 605 houses of all type were partially damaged. On the small island of Culebra, 74 houses were totally destroyed and 89 were partially affected. Public schools suffered an estimated $20-$25 million dollars in damage. All of the islands 401 shelters were opened during the storm and housed 29, 107 people. An estimated $1,673,529,890 in damages was caused to municipalities and $233,496,484 in damages to Commonwealth agencies. Thus, the total damage in Puerto Rico was estimated at $1,907,026,374. Landslide hazards are also a growing concern in Puerto Rico. Bursts of heavy rainfall from intense storms trigger numerous landslides in the mountain areas of the island every year, causing substantial property damage and sometimes loss of life. Construction on vulnerable slopes exposes population particularly in rural areas to these hazards. In 2010, it was estimated that 49% of the population in Puerto Rico lives in areas ranging from moderate susceptibility to landslides to the highest susceptibility.

Hazards in Puerto Rico
Tropical Storms & Hurricanes
Coastal & Riverine Flooding
Storm Surges
Winter Swells from Atlantic Winter Storms
Landslides
Earthquakes, Liquefaction & Ground Shaking
Tsunamis
Erosion
Drought

Through PRCCC partner, Puerto Rico Emergency Management Agency, the PRCCC was able to collect most of the hazard mitigation plans for the

[7] Estimates were calculated combining GIS layers of FEMA FIRMS (2009) and 2010 US Census Data.
[8] Puerto Rico's hurricane season is from June to November.

78 municipalities of Puerto Rico. In brief, existing hazards that affect Puerto Rico today are: riverine and coastal inundation, landslides, tropical storms and hurricanes, earthquakes, tsunamis, winter swells, coastal erosion and drought. Structures that are considered at-risk due to the already existing hazards listed are: residential homes, power generation plants, sewage systems, cemeteries, recreational areas, community centers/libraries, government buildings and facilities, schools, and hospitals. Working Group 3 determined through discussions and the use of the municipal hazard mitigation plans that, according to the historically observed climate trends, Puerto Rico is currently at-risk from:

- Continuing development in high hazard areas or poor drainage areas
- Increasing land use change and area of impermeable surfaces
- Inappropriate use of shoreline stabilization structures in certain areas
- Poor maintenance of existing shoreline stabilization structures
- Poor maintenance and dredging of rivers, canals and reservoirs
- Inadequate capacity and poor maintenance of storm-water management systems
- Poor soil management practices on land and coastal watersheds
- Inadequate construction practices that do not follow established codes
- Elimination of dunes, reefs, mangroves, and other naturally protective features

Of all the hazard mitigation plans for Puerto Rico's municipalities only Naguabo, Peñuelas, Yauco, Hatillo, Salinas, and Toa Baja mention the terms "climate change", "global warming", or "sea level rise".

The socioeconomic conditions and existing vulnerabilities in Puerto Rico described above are the most important considerations when addressing how to meet the new challenge of climate change. The changes in climate that the PRCCC's Working Group 1 report described - will not necessarily create new vulnerabilities for Puerto Rico, but rather are expected to exacerbate the existing vulnerabilities Puerto Rico already faces today. The high proportion of population living in areas vulnerable to natural hazards, growing numbers of the elderly and other at-risk groups, and a relatively high poverty rate (by U.S. if not Caribbean standards) increase the island's social and economic vulnerability to climate change impacts. At the same time, Puerto Rico's relatively high per capita fuel and energy consumption – in electricity and transportation (one automobile per 1.3 Puerto Ricans) – contributes to the causes of global climate change. Municipalities in Puerto Rico are already concerned about climate change as evidenced by the following excerpt from one coastal municipality's hazard mitigation plan: "It is expected that as the years pass the likelihood of flooding in [the municipality] and Puerto Rico in general will increase because of all the climate changes that are occurring in the world." When assessing how climate change could affect Puerto Rico it is important to consider that the real concern is how Puerto Rico's way of life will change, rather than the change itself. An informal survey by the PRCCC to coastal municipalities

> **"The [municipalities], through their history, have suffered from floods and landslides, as has the rest of Puerto Rico. At the global scale, no other type of disaster exists that compares to flooding because of its high frequency and for being the principal cause of life and property lost. The combination of weather events, such as hurricanes and heavy rains, with the location of properties (residential and commercial) in vulnerable flooding areas or poor drainage areas, increases the incidence of these phenomena in [Puerto Rico's municipalities]."**
>
> **Excerpt taken from the Multi-Hazard Mitigation Plans of multiple municipalities in 2005 and 2006**

showed that, according to municipal planners, public works officers and emergency managers, the most concerning social issues affecting their communities are crime and drug addiction, unemployment, housing, poverty or low income levels, loss of industry, school dropout rates, and coastal erosion. Climate change should not be considered a separate social issue, but rather another stress on the already existing vulnerabilities and social issues. This Working Group 3 report is a first attempt to identify and highlight these topics. Future work is needed to expand and refine the information provided.

Working Group 3 Report Organization

The PRCCC Working Group 3 Society and Economy Report describes the existing vulnerabilities to natural hazards and climate change by sector (Table 1) and assesses how the climate parameters temperature, changes in precipitation, sea level rise, and changing storm intensities could affect each sector. To validate preliminary results of the vulnerability assessment, the society and economy Working Group 3 and PRCCC partners conducted risk assessment workshops with coastal municipalities on March 6th and 8th, 2012: *Workshops for the Evaluation of Current and Future Risks in the Coastal Zone*. Thirty of the forty-four coastal municipalities of Puerto Rico attended with representatives from planning offices, emergency managers, and public works officers (figure 1). The PRCCC coordinators presented the preliminary findings of the Working Group 1 (Geophysical and Chemical Scientific Knowledge) and WG 2 (Ecology and Biodiversity), and through a series of facilitated small group discussions the participants confirmed the main climate stressors impacting important sectors of their municipalities (e.g., infrastructure assets, economic development areas, and natural resources); further quantified the magnitude and likelihood of impacts occurring for the features assessed; and discussed the linkages between Island-wide concepts and municipal realities. Additionally, the last session of each workshop was devoted to the brainstorming of adaptation strategies by sectors identified as the most important by the workshop participants. Many of the consequences of certain climate stressors that the Working Group had identified as possibilities for the future, the municipal representatives identified as already occurring. This information was factored into the final results of this report, specifically into the development of a risk matrix.

The changes in climate that the PRCCC's Working Group 1 report described - will not necessarily create new vulnerabilities for Puerto Rico, but rather are expected to exacerbate the existing vulnerabilities Puerto Rico already faces today.

Additionally, as with the reports from Working Groups 1 and 2, Working Group 3 solicited peer reviews and received comments for individual sections and the overall report.

Figure 1 The PRCCC conducted two *Workshops for the Evaluation of Current and Future Risks in the Coastal Zone*. Planners, public workers officers and emergency managers of these 30 municipalities attended on either March 6th or March 8th, 2012.

Working Group 3: Society and Economy
Sectors Assessed

- Critical Infrastructure
    - Stormwater and Wastewater
    - Energy Generation
    - Air and Sea Ports
    - Public Buildings and Structures
    - Private Buildings and Structures
- Water Resources
    - Economic Development
    - Manufacturing
    - Tourism and Outdoor Recreation
    - Cinema
    - Livelihoods
- Historical and Cultural Resources
- Naturally Protective Coastal Features

Climate Change and Puerto Rico's Society and Economy (by sector)

Critical Infrastructure

Climate change is challenging the way critical infrastructure agencies such as the Puerto Rico Aqueduct and Sewers Authority, the Electric Power Authority, the Department of Transportation and Public Works, as well as the Health and Education departments plan for the future. Observed warming and climate model projections (see PRCCC Working Group 1 report) now call into question the stability of future conditions for existing and future infrastructure. Sea level rise may impact the operations of assets like roads and highways, telecommunication networks, important buildings and facilities, electrical power providers and generators, as well as bridges and ports. Increased frequency and intensity of storm surges could close down port operations, drastically increase flooding near critical infrastructure assets and have other consequences. With changes in water quantity and quality, water utilities may be greatly affected. In the face of climatic changes, we must reconsider existing assumptions relative to infrastructure capacity and vulnerability. The PRCCC was unable to find the infrastructure category in Puerto Rico with the greatest total capital investment on the island, however, according to one newspaper article, managing issues related to water quality alone could cost Puerto Rico about $4 billion in infrastructure (Millán 2011). With such investments, planning for future scenarios becomes even more critical to avoid a situation where new infrastructure quickly become obsolete. The challenge is that with anthropogenic warming past climate is no longer a reliable guide to the future.

A critical facility is defined as a facility in either the public or private sector that provides essential products and services to the general public, if otherwise necessary to preserve the welfare and quality of life in the community, or fulfills important public safety, emergency response and/or disaster recovery functions. Infrastructure, as the Latin root of the term suggests (*infra* meaning "below" or "beneath"), refers to an interconnected system of assets and services that are not readily evident, yet provide critical functions to society. The great importance of infrastructure becomes apparent in its absence. We take for granted most of the infrastructure services we rely on in our daily lives, yet when they are suspended their inherent value becomes clear. In most cases the "value of infrastructure derives from the service it provides" and how many people it provides it to. For this reason it is important to qualify and quantify the vulnerability of critical infrastructure systems. Climate stressors associated with climate change, particularly sea level rise, increased temperatures, changes in precipitation patterns, and hurricanes of increased intensity, are anticipated to directly impact these systems and disrupt essential services.

This section attempts to identify the critical infrastructure in Puerto Rico that would be negatively impacted by the following climate stressors associated to climate change: (1) flooding and storm surge as a result of sea level rise; (2) increased average air temperatures; (3) changes in precipitation patterns; and (4) more intense tropical storms and hurricanes. The critical infrastructure is outlined into sections and then divided into more specific sub-sections. The existing vulnerabilities to critical infrastructure due to the aforementioned climate stressors are identified and described. In this regard this report is qualitative and does not intend to quantify the amount of infrastructure that would be vulnerable to the effects of climate change. Quantifying the critical infrastructure assets and the services they provide that would be negatively affected

[10] Esther Conrad, Climate Change and Infrastructure in the Gulf of Mexico and Caribbean Basin: New Risks to Building Blocks of Resilience.

is essential to properly determine priorities and plan an adequate adaptation strategy. The PRCCC recommends a more-specific vulnerability assessment be done for Puerto Rico's most important assets at the agency level, municipal level, and the site level. This report is meant to lay the groundwork for these future assessments.

Energy

Power Generation Plants

Most of the energy in Puerto Rico is generated by the burning of fossil fuels and all of the major power generation plants are located on the coast. The main reason is that most of the fuel is unloaded by ocean vessels to the plants. There are some hydroelectric generators located further inland, but they constitute a small fraction of the energy potential in Puerto Rico. Accordingly, all of Puerto Rico's power generation plants are at risk of structural damage due to flooding from sea level rise, floods, and storm surges. Additionally, the higher temperatures associated with climate change could also result in an increased demand for electricity to be used for cooling, further taxing the system. Seventeen power generation plants are located in Puerto Rico on the coast. It is known that two of the generation plants were susceptible to floods caused by tsunamis. These two power plants are the Palo Seco and Turbinas De Gas Mayaguez power plants. Four others could also be inundated by future storm surges: Costa Sur, Turbinas De Gas Mayaguez, San Juan Steam Plant and Palo Seco. According to a Worchester Polytechnic Institute Study (2011) that was completed for the Puerto Rico Coastal Zone Management Program and used available flooding data two plants affected in particular would be the Turbinas De Gas Mayaguez and the San Juan Steam Plant, both located in the FEMA AE flood zones, deemed high risk areas.

Transmission and Distribution

The PRCCC was unable to find Puerto Rico specialists on transmission and distribution system and climate change, thus PRCCC was unable to conduct a detailed analysis of potential stresses for the 2010-2013 report. However, according to PREPA, as of September 30, 2012 there were 2,450 circuit miles of transmission lines and 32,548 circuit miles of distribution lines. The total length of transmission lines within the coastal region is 161 miles (WPI 2011). Flooding in the coastal zone from sea level rise, increased storm intensity and associated storm surges could result in structural damage to transmission line towers, substations and transformers. Past storm events indicate that Puerto Rico's transmission and distribution system is already affected by weather events and frequently suffers from losses in services. Therefore the system may not be able to withstand increased flooding events in its current form. This situation has prompted PREPA to complete an underground 115kV transmission circuit line around the San Juan metropolitan area in order to reduce power loss incidents in the aftermath of hurricanes and other major storms that strike Puerto Rico. Additionally, they have improved underground 38kV lines in Vega Baja and Mayaguez and are improving 38 kV subtransmission systems by constructing underground lines in Carolina, Guaynabo and San Juan. Other projects may be planned by PREPA for other parts of the island and would be expected to significantly improve the reliability of the sub-transmission system. More information is needed to assess the whole transmission and distribution system as related to climate change and the PRCCC recommends a thorough analysis to be completed in the near future.

Communications

The PRCCC was also unable to find specialists on communication infrastructure and climate change in Puerto Rico, however, anecdotally at multiple public meetings and municipal risk assessment workshops the issue of lack of communications after storms was often raised. This is an issue of great importance in terms of both emergency management and economic development. Response efforts after storms, heavy rain events, earthquakes and landslides require adequate communications. Additionally, many industries rely on stable communication services and interruptions in services disrupt production (Puerto Rico Manufacturers' Association *personal communication* 2012).

Transportation

Roads, Bridges and Associated Structures

The Commonwealth's approximately 26,718 km of paved highways, roads and streets (Government Development Bank for Puerto RicoeeJuly 2011/ Department of Transportation and Public Works 2010) and other associated infrastructure come in many shapes and sizes, and with differing surfaces and foundations. The road density in Puerto Rico is 298 per 100 km^2. Like other infrastructure, roads and bridges are not expected to escape the effects of climate change. However, little documented information is so far available examining the topic. Traditionally, roadway design in Puerto Rico has proceeded on the assumption of static climate conditions where historic weather data provided adequate roadmaps for future designs.

Long-term fluctuations in temperature associated with climate change could cause thermal cracking. Higher in-service temperature for roadways could increase the potential for rutting and generally, maintenance, rehabilitation and reconstruction will be needed earlier in the design life. Climate change effects on transportation infrastructure also include the increased vulnerability of roadways, particularly low-lying ones, to increased vulnerability from flooding due to precipitation and sea level rise, coastal floods and erosion, more frequent and intense rainstorms, or from overflowing streams and water bodies. Bridges, depending on their height, may need to be raised if the water bodies they cross increase in water level due to increased precipitation or sea level rise. New bridges design may also need modification, construction and maintenance to account for additional flooding. Existing bridges may have to be raised to accommodate higher flood or sea levels, as was done in the municipality of Peñuelads after Hurricane Georges. The hurricane destroyed three bridges, and the Río Tallaboa bridge had to be raised to avoid future problems. As the seas rise more bridges around Puerto Rico will need to be raised. This is especially true for low-lying bridges. On the main island of Puerto Rico, there are 240 bridges located within the coastal zone. Many are used to pass over rivers or wetlands on coastal routes. Mapping by WPI showed that there are at least 30 bridges that are potentially vulnerable. Since the heights of the bridges were not able to be obtained, a more thorough analysis of inundation was not possible. These bridges constitute important links to the communities they serve. Flooding from sea level rise could result in structural damage to bridges, or they might become completely submerged and therefore unusable.

Roads are absolutely essential in Puerto Rico because most of the transportation is conducted by private car and commercial vehicles. In fact, 89% of work related trips are done by private vehicles, according to the 2000 Census. Because most of the urbanization in Puerto Rico is in the coastal zone (40%), this area contains a large proportion of the roads on the island. Flooding from sea level rise could result in structural damage to roads, or they might become completely submerged and therefore unusable. And because asphalt softens in high heat, roads will require more repair more often as they are exposed to the higher projected temperatures.

Mass Transit (Passenger Rail and Buses)

Puerto Rico has a relatively new passenger rail system in the San Juan metropolitan area. Even though most of the system is elevated, there are potential risks. In particular, flooding in the coastal zone could result in structural damage to passenger rail stations, or they might become completely submerged such that the system will not be accessible at those points.

Many bus routes and other mass transportation vehicles in Puerto Rico have coastal routes and inland routes that are frequently flooded. As these areas become more inundated from sea level rise or the increase in downpour events travel routes may have to be reconfigured. New projects, like the Metro Urbano which consists of building a special lane along PR-22 that will be used for a new bus rapid transit (BRT) system to connect Toa Baja to the final urban train station stop in Bayamón, may experience flooding during certain events that could be avoided if future scenarios are factored in during the planning and construction processes. By planning today for future flooding scenarios we can avoid costly investments and cut down on traffic congestion in the urban areas.

Passenger Ferries

Passenger ferries are especially important in the eastern coast of Puerto Rico, because it is the main form of transportation for most residents of the island municipalities of Vieques and Culebra. Passenger ferry terminals are especially vulnerable to the effects of climate change. Flooding from sea level rise could result in structural damage to the passenger ferry system or cause the same to become completely submerged and therefore unusable. On the other hand, demand for passenger ferries may increase as bridges and roads become inundated and certain roads impassable.

Ports

Airports

Puerto Rico has both international and local airports located within the coastal zone. As an island, Puerto Rico relies on air travel infrastructure for most of the passenger movement to and from the island. Flooding due to sea level rise could completely impair the use of airport runways, cause structural damage to airport buildings, and prevent access to the airport. Two notable cases are the Luis Muñoz Marín International Airport and the Isla Grande Airport, both located on the coast and at great risk to from sea level rise. Higher overall temperatures can also cause thermal cracking of the airport runway tarmac.

Of the fourteen airports that are located in Puerto Rico, only five are situated along the coast. The Antonio Rivera Rodriquez Airport is located on the island of Vieques and the Culebra Airport is located on the island of Culebra. There are three airports situated along the coast on the main island. These Airports are the Patillas Airport located in Patillas, the Luis Munoz Marin International Airport in San Juan, and the Fernando Luis Ribas Dominicci also located in San Juan. It has been reported that the airport in Ceiba has plans to expand in the future. All these coastal airports are at risk to possible future sea level rise.

Possible climate change impacts to airports in Puerto Rico are flooded runways, flooding of out-buildings and access roads, and disruption to fuel supply and storage.

Seaports

As with airports, seaports represent one of the most important infrastructure elements in Puerto Rico. Most of the food consumed on the island is imported, and a great part of Puerto Rico's economic activity relies on the import and export of goods. Climate change could affect the operation of the different types of ports on the island: cargo ports, used principally for imports and exports of goods; cruise ship ports, used principally for tourism; fishing ports, used by fishermen for their commercial activities; and marinas, used by owners of recreational water craft such as power boats and sail boats. Sea level rise creates a unique challenge for seaports as all functions are closely associated to the current levels of the sea. Flooding from sea level rise could cause structural damage to docks, buildings and heavy machinery, and eliminate much of the surface area currently used adjacent to the water.

Arecibo seaport already experiences regular problems with their platform due to the port being a high wave energy area. Additionally, the Pan American dock in San Juan frequently experiences riverine flooding. Ponce's port reportedly shuts down at least once a year due to riverine flooding as well. There are no known capital improvement plans for maritime transport by the Puerto Rico Ports Authority as the ports have many different tenants and operations requirements and capital improvement plans would be determined by the individual companies (Ports Authority, *personal communication,* July 18, 2012). The PRCCC recommends a more in-depth analysis of Puerto Rico's ports and vertical measurements relevant to sea level as this is outside the scope of this report.

Waste Management and Recycling

According to the U.S. Environmental Protection Agency, "The management and disposal of solid waste – more commonly trash or garbage – in Puerto Rico has long been a challenge. The problem is intensified by the limited disposal space available on an island community and Puerto Rico's delicately balanced ecosystem." (EPA 2012). Puerto Rico residents generate more waste than U.S. mainlanders and recycling rates are lower as well. Much of Puerto Rico's solid waste ends up in one of the island's 32 landfills, most of which do not comply with Commonwealth and federal landfill requirements (EPA 2012).

Flooding due to sea level rise could open landfill layers and release chemicals and solid waste (i.e., trash) into the ocean and subsequently damage or destroy marine ecosystems. More intense storm events could mean that roadways will become inaccessible after storms. This would disrupt waste management as it is currently run on the island, as it would impede the movement of solid waste to landfills and recycling facilities. A detailed analysis would need to be conducted to determine land fill proximities to potential sea levels.

The Industrial Landscape and Brownfields

There are 29 Superfund sites between the National Priorities List and the Resource Conservation and Recovery Act. The majority are related to petrochemical and pharmaceutical production or Naval Base activities (EPA 2008). There is a great risk to the closed oil refineries in Puerto Rico as they are located extremely close to the coast and are at great risk of flooding due to sea level rise. Flooding events could cause environmental degradation, contamination, and affect coastal and marine ecosystems. Flooding could also cause underground storage tanks at operating gas stations to break and spill their contents, causing the migration of pollutants to the water table through percolation and direct contact with infringing surface waters.

Buildings

Puerto Rico's thousands of buildings exist in a bewildering array of sizes, shapes, designs, and configurations and perform many functions. This is the case with: (1) public infrastructure systems, including government, police and fire stations, educational, health, cultural, recreational, transportation terminals, public housing, certain hospitals, prisons and other facilities; (2) para-public infrastructure, including churches, sports venues, certain hospitals and transportation terminals, which though privately owned, receive widespread public use; (3) privately owned and privately used structures, including single, detached dwellings like single-family homes, multifamily homes, office buildings, commercial buildings, shopping malls, and hotels.

Traditionally, designers of Puerto Rico's buildings relied on the built-in assumption that the climatic patterns present at the time of design and construction would stay fairly constant throughout the structure's useful life. However, information in this report and myriad other sources now casts serious doubt on assumptions about climatic conditions staying constant. The data point to possibilities of some fairly rapid climatic changes. Supporting evidence for this comes in the form of increasing temperatures, rising sea levels, higher average wind speeds, as well as changing precipitation patterns.

In many cases, climate change could leave Puerto Rico's buildings vulnerable to:

- Technical inabilities to cope with failures, with resulting harm to occupants, equipment and materials;
- Disruption or limitations in the delivery of services; or
- Added costs in the delivering of services (such as from increasing cooling costs due to higher air temperatures).

Engineers, consulting firms and other involved in the design, construction, maintenance, operation and use of buildings will be called upon to identify and respond to such vulnerabilities. Many factors could come into play and have to be considered – among them:

- Building materials, building envelopes and building stability;
- Accelerated physical weathering, due to changing atmospheric physical, chemical properties and biological – including wind-driven rain and abrasive materials, broad-spectrum solar and ultraviolent radiation; mould, mildew, rot and possible pest infestations;
- Effective function of air and vapor barriers;
- Impacts related to water levels – notably in flood plains and coastal areas;
- Shifting daytime and night-time heating patterns;
- Changes in ground conditions
- Wetter conditions leading to wetting and drying, moisture and penetration of doors, windows and other areas;
- Maintenance challenges and, due to climate changes, widening of existing infrastructure deficits
- Need to apply revised building codes and standards, as well as design values relating to expected changes in frequency of certain weather events;
- Resiliency, strength and durability of materials – including concrete, stone, masonry, and plaster – and how they are used;
- Structural integrity of walls and roofs in the face of stronger winds, and more frequent and intense precipitation; and
- Heating ventilation and cooling – including possible lessened reliance on fossil fuels (for heating) and more dependence on electrical power (for cooling).

The degree of change, consideration of different factors and the consequences will differ from municipality to municipality. Furthermore, it is difficult to forecast the magnitude of certain anticipated changes, especially those related to wind, using current climate models. With rare exceptions, buildings are not stand-alone infrastructure. Almost invariably, buildings need the support of other infrastructure – be it water supply, sewer, roadway, electrical or communications systems. Failures in any of these systems, possibly a sewer backup brought on by sudden flooding, can affect individual buildings. The buildings, in turn, may house critical components (power generation, water treatment, instrumentation, etc) of the supporting infrastructures. In short, buildings left vulnerable to climate change may expose other infrastructure to vulnerability. Choices made today for new and existing building could either intensify or mitigate buildings' vulnerabilities to climate change in coming decades.

Some technical inabilities to cope with such failures and disruptions are expected, resulting in harm to occupants, equipment and materials. This in turn, might cause disruption or limitations in services delivery and operations, as well as added costs in delivery of any services. Lastly, older structures may be more at-risk due to the likelihood of construction before building codes and planning and zoning requirements were implemented.

Climate change imposes a unique challenge to all coastal cities and communities, as many of the island's buildings could be at risk, depending on their locations. Most of the people in Puerto Rico live within the coastal zones and thus public, para-public, and private buildings are also mostly located in the coastal zones. The San Juan Metropolitan Area and the cities of Ponce and Mayagüez, the three largest cities in Puerto Rico, are all coastal cities. In the San Juan Metro Area, the most densely populated areas are right on the coast. Neighborhoods like Condado and Isla Verde are populated by various multi-family housing towers, hotels, and businesses at close proximity to the water.

The principal risk associated with climate change and buildings is that of structural damage from the impact of flooding from changes in precipitation, sea level rise, and storms. Structural damage can make a building unusable if it becomes a safety risk to human life. The location of these structures is the primary way to determine vulnerability to future conditions. For instance, a rough analysis shows on the main island of Puerto Rico there are approximately 62 hospitals located within the coastal zone. Of these, eight hospitals are vulnerable to tsunamis, potential sea level rise, and storm surge. Of the 2,398 schools located on the mainland, 310 reside in the coastal zone and 26 schools may be potentially susceptible to storm surge, sea level rise, and tsunamis.

In regards to hotels, a study from the WPI team interviewed representatives of an upscale resort located in Condado. The manager of the hotel stated the biggest problem facing the hotel was coastal erosion. Every few months, new sand must be added to the beach (WPI 2011). Renace Condado is an organization working towards improving the quality of life in Condado; one of its concerns is beach erosion. People from different support sponsors meet regularly to discuss how to better protect the area and prevent more damage from occurring. There was even an attempt at securing the sands by planting palm trees to stabilize the beach; however, these trees were easily swept away right along with the sand. Years ago the coastline was a good distance from the hotel but as the years have gone by the shore has lost its width. The interview subject mentioned that during stronger storms, the water hits the walls of the hotel. In an effort to protect these walls, a much stronger type of glass was used which can withstand winds of up to 120 meters per hour. This prevents the water from actually entering the building. Sandbags are also utilized in an effort to protect against flooding in the event that a larger storm impacts the area. In the event of a hurricane or flooding, the hotel manager stated the hotel would lose power. Backup generators are located in the underground parking lot and are used to ensure the computer systems and phone lines stay operational. This generator does not power the rooms themselves. Because the generators are located at the basement level should there ever be a substantial amount of flooding, the generators would not be operational and the building would lose power completely.

Historic and Cultural Sites

Puerto Rico has a wide variety of buildings that have historic and cultural significance, many of which are located on the coast. A sampling of these would include the Spanish forts of Old San Juan, as well as the series of light houses, churches, and historic homes located around the island. Many coastal towns, such as Cataño, Hatillo, and Arecibo, have their historic city centers located adjacent to the water and vulnerable to the effects of climate change. Information collected by Working Group 3 during risk assessment workshops with the coastal municipalities indicates that certain historic properties in Puerto Rico are already exposed to flooding events, such as the Catholic church *Santa Rosa de Lima* in Rincón and remnants of the old train along the west coast, *Antigua Casa de la Real Aduana* **in Fajardo,** numerous archaeological sites of Taino and Spanish artifacts (e.g., cooking areas and canons), the ruins of *Hacienda María Antonia* in Guanica, and *Castillo Villa del Mar* in Naguabo. In fact, the remains of the Castillo in Naguabo, located on route 3 and one of the few examples of late Victorian architectural style in Puerto Rico, has already suffered serious damage from Hurricane Hugo in 1989. Despite that tragedy and a subsequent fire the municipality and other government agencies are hoping to restore the building. Increased frequency of flooding from sea level rise and heavy precipitation events could cause more structural damage to this historic building and many others, perhaps even complete loss of such treasures.

Examples of Potentially Vulnerable Historical Sites in Puerto Rico

- *Spanish forts in Old San Juan*
- *Various archaeological sites of Taino and Spanish artifacts (e.g., cooking areas and canons)*
- *Historic city centers (e.g., Cataño, Hatillo, and Arecibo)*
- *Rincón church: Santa Rose de Lima*
- *Fajardo's Antigua Casa de la Real Aduana*
- *Ruins of Hacienda María Antonia in Guanica*
- *Castillo Villa del Mar in Naguabo*
- Church San Carlos Borromeo of Aguadilla
- *Old Municipal Cemetery of Aguadilla*

Water Resources

Urban modes of development have increasingly divorced us from our natural environment where water plays a vital role. Climate change is expected to exacerbate water regimes in extensive macro-regional swaths with impacts in both large and small scales of development. Puerto Rico's water resources are key assets that exist at both the surface and subsurface levels. Surface water resources are lakes, reservoirs, dams, rivers, wetlands, streams and canals (figure 2).

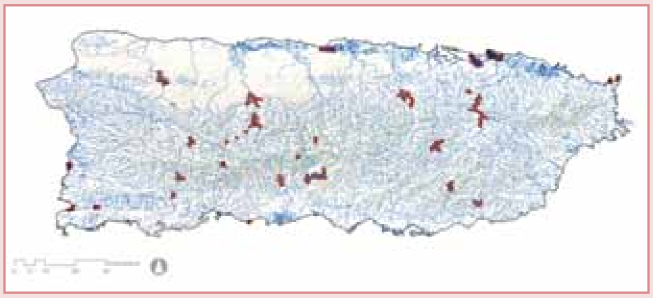


Figure 2: Surface Water Resources: Lakes, Reservoirs, Dams, Rivers, Wetlands, Streams and Canals. Map Source: ae.i.ou. 2009. Based on data collected from USGS. Lakes, Reservoirs, Lagoons (red outline), rivers, canals, and streams (blue lines)

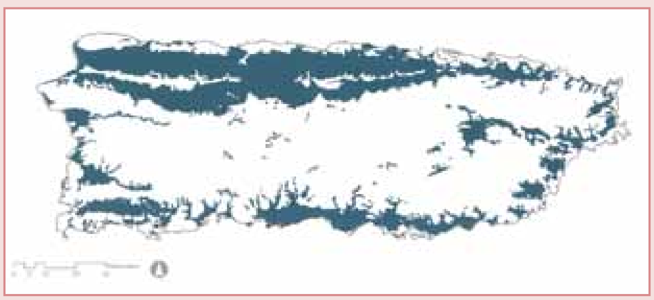


Figure 3 Groundwater & Subsurface Water: Aquifers, Saturated Zone, Subsurface Infiltration. Map Source: ae.i.ou. 2009. Based on data collected from USGS. Aquifers, Saturated Zone (blue color)

Groundwater and Subsurface water resources are aquifers, saturated zones, and subsurface infiltration zones (figure 3).

Traditionally, water resource planning has used recorded weather and hydrology to represent future supply conditions. Many sophisticated methods are used for reconstructing, resampling, and analyzing hydrology and other weather-related conditions. It was assumed that the hydrologic determinates of future water resources – temperature, precipitation, streamflow, groundwater, evaporation and other water dependent factors – would be the same as they had been in the past. While there may have been large variations in observed weather, it was assumed that weather statistics would stay the same and variability would not increase in the future. This core planning assumption is often referred to as *climate stationarity* (Edward Means III 2010). Now, we must plan for a changing climate.

Water is vital to all sectors and aspects of life in Puerto Rico – including human health, agriculture, industry, local governments, energy production, recreation and aquatic systems. Research and scientific literature present mounting evidence that climate changes will alter where, when and how precipitation falls and water flows. This, in turn, will impact the quantity and quality of surface water and groundwater. Water's essential importance to human health, the economy and the environment means that water resources facilities are among the most critical and perhaps the most vulnerable categories of infrastructure relative to climate change. Many questions remain regarding climate change's impact on water resources infrastructure and how water resources infrastructure can and will respond to climate change when added to other human induced impacts such as sedimentation of water reservoirs and lakes which greatly reduce freshwater storage capacity.. This report is part of the search for answers.

The global impacts of climate change on freshwater systems and their management are mainly due to the observed and projected increases in temperature, sea level and precipitation variability (Kundzewicz et al 2007). Sea-level rise will extend areas of salinization of groundwater and estuaries, resulting in a decrease in freshwater availability for humans and ecosystems in coastal areas. Increased precipitation intensity and variability is projected to increase the risks of flooding and drought in many areas. Higher water temperatures, increased precipitation intensity, and longer periods of low flows exacerbate many forms of water pollution, with impacts on ecosystems, human health, water system reliability and operating costs. These pollutants include sediments, nutrients, dissolved organic, pathogens, pesticides, salt, and thermal pollution.

Vulnerability assessments for public infrastructure have been completed around the world (APEGBC 2010; NYPCC 2010). To our knowledge, none have been completed for Puerto Rico. Results from other vulnerability assessments have found that climate change affects the function and operation of existing water infrastructure as well as water management practices. The functioning of existing facilities that are not designed to accommodate climate change impacts (different temperatures, precipitation and flow changes for example) may increase the chances of infrastructure failure, insufficient supply, inadequate protection from floods and unacceptable water quality conditions.

Aspects of water resources likely to be influenced by climate changes include the following, in brief:

- Seasonal shifts in stream flows that could lead to increased and decreased flows in certain seasons. This could impact water storage and electrical power generation and cause possible flooding. In the longer term, this also means depletion of water storage.
- Greater and more intense precipitation events and lengthened dry spells in given locations could increase both flooding and drought.
- Higher water temperature and more intense precipitation, accompanied by extended periods of lower flows, could increase water pollution. By extension, this could impact the ecosystems, human health as well as the reliability and operating costs of water systems.
- Droughts and decreased availability of water may reduce streamflows, lower lake and reservoir levels, deplete soil-moisture reserves and diminished groundwater reserves. By extension, this will likely aggravate water conflicts between various users.
- Sea level rise could extend existing areas of salinization of groundwater estuaries leading to less available freshwater for human populations and ecosystems.

Generally, higher evaporation associated with warming trends tends to offset effects of more precipitation while magnifying the effect of less precipitation. Climatic shifts and resulting changes in available water resources could require modifications in water allocations. Such changes could require adjustments to the design, construction, maintenance and operation of water resource infrastructure supplying municipal, industrial, and agricultural water users. It could prompt consideration of the robustness, vulnerability, and adaptive capacity of current infrastructure, as well as whether additional water resource infrastructure might be needed.

Some specific categories of water resource infrastructure that might be subject to climate-change consideration are listed below:

- **Dams, Reservoirs and Hydropower:** Dams help to reduce flooding, allow harnessing of energy and provide for reliable water sources for domestic, industrial and agricultural use. Puerto Rico withdrawals 15.73 million gallons per day of surface waters from dammed water bodies in order to irrigate 40.83 thousand acres of agricultural lands and golf courses (DNER Plan de Agua 2010). And in 2008, Puerto Rico had 36 reservoirs (PIRA 2008). Issues arising in connection with dams include long-term supply and availability of water. Changes in precipitation patterns raise questions about erosion, dam failure, safety and contingency planning. Besides supporting electrical generation, dams along with diversions and dykes can control or reduce flooding.

- **Irrigation and Drainage Infrastructure:** Climate change could increase needs for dams, reservoirs, and diversions to meet added demand for irrigation. Other adaptive infrastructure traditionally used – such as wells, pipelines and dugouts – may also be called into use. Besides obtaining water when there is too little, agriculture must remove excess water from crop-producing areas, often via drainage ditches. Climate change may produce increased run-off and require added infrastructure to handle this excess water.

- **Water Supply and Treatment:** The vast majority of water in Puerto Rico is used for household consumption. Climate change could affect water systems and supply sources. The timing and availability of water could vary if annual and seasonal rainfall increase, and if rainfall events are more frequent and intense. Higher temperatures could reduce available water or cause droughts leading to water supply shortages. Changing patterns of flooding could affect intakes of water systems. Both drought and flooding could require additional water treatment, thereby placing further demands on treatment plants. Additionally, treatment plants on the coast could be affected by storm surge and storms. When there are power outages during storms the treatment plant pumps stop working and can cause sewage overflows.

- **Industrial Water Supply:** Water is critical to manufacturing and thermal power production for cooling, condensing and steam generation, and for conveying waste material. Higher temperatures may increase industrial demand by industry for cooling at a time when water supplies could become scarcer.

Unaccounted-for Water in Municipal Water Supply

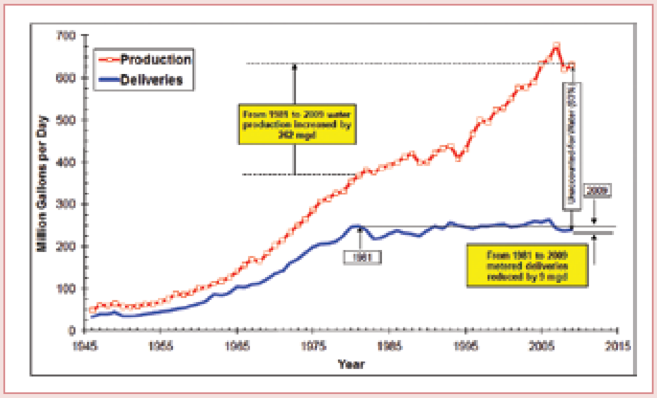


Figure 4 Unaccounted-for water trend for PRASA's water production. Source: PRASA 2010

One of the biggest threats to achieving sustainable water supply for all uses (domestic and industrial consumption, irrigation, hydroelectric, recreational, fish and wildlife refuges, etc.) is the increasing trend of PRASA's Unaccounted-for Water volume. In 2009, 63% of all of PRASA's water production was unaccounted-for water, which translates into Non-Revenue Water (NRW) for the public corporation (figure 3). Such a high volume of NRW might compromise safe yields in a future where a changing climate may reduce precipitation in many of the available reservoirs.

[11] References: Puerto Rico Aqueduct and Sewer Authority (2010). *Study of Desirability and Convenience for the Implementation for Advanced Technologies for the Reduction of Non-Revenue Water*. Puerto Rico Public-Private Partnerships Authority.
Puerto Rico Department of Environmental and Natural Resources (2008). *Plan Integral de Recursos de Agua de Puerto Rico.*
Gregory Morris Engineering PSC (2009). *Water Accountability Pilot Project Final Report.* Puerto Rico Aqueduct and Sewer Authority.

NRW has two possible types of water loss or sources. The first and main one is physical losses, which includes leakage in water mains, water main breaks, storage tanks overflows and leaks, and hydrant use for firefighting and other authorized, but unmetered uses. The second one is commercial losses, which comprises theft or unauthorized consumption, metering equipment deficiencies, meter estimates or misreads, and PRASA customer database problems.

During future drought periods, an increasing trend in NRW could substantially compromise water availability, which could cause water rationing that will ultimately affect the island's economic interests (industrial, commercial, touristic, etc.), availability for irrigation, fish and wildlife refuge sustenance, as well as the most vulnerable populations (sick, elderly, etc.). Institutionally, this scenario has serious and stressful implications, not only for PRASA, but also for PREPA, PRDNER, PRDH, PRDA, and the PRPB. PREPA is the public corporation with jurisdiction over irrigation channels, and the PRDA has state jurisdiction over agricultural matters. PRDNER has various fish and wildlife refuges located in many of the reservoirs, and an unstable water level could have serious repercussions on aquatic life. The health impacts of water rationing can cause additional and unsuspected institutional stress on the PRDH. Land-use planning that has had deteriorating consequences over water distribution can cause sudden institutional burden on the PRPB.

Although PRASA has implemented various projects to reduce NRW (a pipe pressure stabilizing project to reduce physical losses, and the NRW Reduction Program to reduce commercial losses), their degree of success has yet to be measured in a recent water balance. A land-use master plan that aims to reduce stress on the water distribution system has not been approved by the PRPB yet. Also, a long-term and wider-in-scope water infrastructure repair and renewal project will be needed to reduce physical losses by a substantial margin. Water conservation and water theft prevention measures at the household level will have to be implemented with interagency and community participation.

Impacts of Specific Climate Stressors on the Water Resources of Puerto Rico

Sea Level Rise

Surface Water Resources: New climate models suggest that sea level rise will have severe consequences on coastal areas where aquatic habitats are important components of the hydrologic cycle. Rising sea levels will affect the tidal regimes that control the hydrology of many coastal ecosystems in Puerto Rico. These habitats rely on the accumulation of organic matter to maintain their profile elevation with respect to sea level. As sea level rise accelerates, some mangrove fringes and wetlands will be unable to keep pace and could be significantly eroded to the open sea and thus may speed up the sea level rise process via coastal erosion. Other coastal wetlands and mangrove forests will be able to migrate inland as sea inundates coastal areas. Roads and buildings as well as insufficient sediment availability could impede wetland's vegetation to migrate inland. Sea level rise will also produce more severe tropical storms, causing storm surges that could significantly affect tidal wetlands through increased coastal flooding and increased salinity of estuaries . In addition, these will completely modify tidal ranges in rivers and bays and bring new forms of contamination in coastal areas and atypical transport of sediments and nutrients that degrade coastal ecosystems.

[12] IPCC, 2007: Climate Change 2007: Impacts, Adaptation and Vulnerability . Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, Martin L., Canziani, Osvaldo F., Palutikof, Jean P., van der Linden, Paul J., and Hanson, Clair E. (eds.)]. Cambridge University Press, Cambridge, United Kingdom, 1000 pp.

Ground Water Resources: Coastal aquifers are important strategic resources that may be at risk of salt intrusion as a consequence of increased coastal flooding due to sea level rise. Timms et. al (2008) points out that: "saline intrusion and/or inundation caused by rising sea-level would probably be the most significant impact on coastal groundwater resources due to climate change, particularly for shallow sandy aquifers along low-lying coasts." Aquifers that could be threatened by SLR are important resources that provide water for many important ecological functions and ecosystem services.

Rising Temperatures

Surface Water Resources: An important driver of land use adaptation will be new temperature regimes resulting from changes in weather, rainfall patterns, and ecosystem loss. Rising temperatures may cause a decline in precipitation and an increase of evaporation, resulting in a substantial drop of fresh water availability in reservoirs and lake systems. Also, the rising heat levels will produce direct increases in the temperatures of rivers and streams which will further exacerbate water stress in some areas. As described by Working Group 1 drought conditions may be increasingly likely for the Caribbean. As a result, climate change is expected to create serious water supply problems in dry periods. In addition, the urban heat island effect -- a process which today leads to more than a 10.8 °F degree increase in urban air temperatures – will also bring about changes. These changes will affect the network of surface water bodies in many cities . And since rivers, streams and wetlands play such a critical role in moderating global climate by capturing and storing atmospheric carbon, protecting biodiversity and mitigating flood impacts , the disruption caused by rising temperatures and urban heat island effect would be further disruptive.

Ground Water Resources: Groundwater supplies will be affected by higher temperatures. The drying off of vegetation swaths produce watershed scale variances that will alter soil composition, making soils less porous, thus reducing groundwater recharge rates. This will in turn increase rainwater runoff, exacerbate flood threats and lead ultimately to mudslides. Less subsurface water also entails that in dry months higher temperatures will cause changes in vegetative cover that could succumb to wildfires and other deforestation hazards.

Changing Precipitation Patterns

Surface Water Resources: Fundamental to climate change is recognizing how design parameters are changing. In this way precipitation will usher in new extremes. Climate change is expected to increase the frequency of heavy rain events precisely in the latitudes where Puerto Rico is located. Higher volumes of stormwater runoff produce more water quality issues when large precipitation events occur. Urbanized land use increases the amount of impervious surface that, in turn, increases the volume of stormwater runoff to be managed. Altered precipitation patterns resulting from climate change threatens rivers and streams as higher pollution levels from runoff could be registered.

Ground Water Resources: The natural processes that recharge aquifers will suffer and could have serious implications for maintaining water supplies in the future. Moreover, measures to combat these issues, like building dams to

[13] Timms, W, Andersen, M.S. and Carley, J (2008). Fresh-saline groundwater boundaries below coastlines - potential impacts of climate change. Coast To Coast Crossing Boundaries Conference, 18-22 August, 2008, Darwin.

[14] Climate Change: Global, Regional, and Urban – An Introduction. Climate Change Literature Review. http://urpl.wisc.edu/ecoplan/content/lit_climate.pdf

[15] Environmental Protection Agency. Heat Island Effect: Basic Information. 2009 http://www.epa.gov/heatisld/about/index.htm 16 Peter H. Gleick, Briane Adams. (2000) Water: The Potential Consequences of Climate Variability and Change for the Water Resources of the United States. Pacific Institute for Studies in Development, Environment, and Security and U.S. Geological Survey.

store water will further impact aquatic habitats by increasing fragmentation that inhibits the movement of flora and fauna over time.

Increasing Intensity of Storm Events

Climate change is increasing, and will continue to increase, the intensity, and possibly the frequency, of storm events. The mounting intensity of storms will require comprehensive action to reduce stormwater runoff and to minimize its impact on Puerto Rico's water resources. Many existing developments were not planned and designed to ensure adequate water sensitive development standards and lessen storm damage. Even modest disruptions to infrastructure can have significant effects on daily life. Projected changea in the frequency or intensity of those disruptions could have profound consequences for economic and human well-being. Future changes in climate that may alter precipitation intensity or duration would likely have consequences for urban stormwater discharge, particularly where stormwater detention and conveyance facilities were designed under assumptions that may no longer be correct. The social and economic impact of increasing the capacity of undersized stormwater facilities, or the disabling of key assets because of more severe flooding, could be substantial. Because a change in climate is expected to affect oceanic and atmospheric circulation that produces more precipitation, we will also see alterations in the intensity, frequency and distribution of tropical storm systems. Bigger storm surges will damage coastal ecosystems by eroding the natural defenses that protect our coasts. Rivers and streams will be overloaded by larger precipitation volumes, and lakes will become flooded by rainwater and by stormwater runoff that carries heavily contaminated pollutants. As the surface water network becomes compromised, overburdened, eroded and ultimately polluted, so will the ground water resources. Hurricane and tropical storm often produce long periods of infrastructural collapse that disrupt water supplies and generate serious water demand stress throughout the population.

Environmental Degradation

The effects of climate change are likely to be exacerbated by a wide variety of human development and polluting activities. Poor land use practices have resulted in sedimentation of river channels, lakes and reservoirs and changes in hydrological processes. Deterioration of the quality of water resources resulting from further increases in nutrient loads from agricultural irrigation and the domestic industrial and pharmaceutical sectors has also significantly affected available fresh water resources. Increased human activities lead to the exposure of the water environment to a range of chemical and biological pollutants, as well as micro-pollutants. The oil refinery and pharmaceutical industrial sectors in particular produce high concentrations of effluents that act as non-point sources of water quality degradation, including the unprecedented effects of unknown chemical interactions which currently pollute our groundwater resources. While oil refineries no longer operate in Puerto Rico areas of previous operation should be assessed for their contamination potential. Environments are already under pressure from human activities that drain natural water bodies and introduce pollutants that wash out to coastal ecosystems, such as mangroves, sea-grass and coral reefs. From a Society and Economy point of view, environmental degradation is enveloped with climate change for the reasons outlined and for many more reasons beyond the scope of this report.

[17] Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, Eds., 2008: Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 pp.

Water Supply

Water supply infrastructure constitutes all of the elements that relate to the processing and distribution of potable water for consumption. Water supply infrastructure includes, but is not limited to storage structures, main water pipes, etc. Because water is essential to human life, water supply infrastructure should be considered essential to health and livelihoods in the context of climate change.

Sea level rise will likely cause the salinization of aquifers, creating a need for higher levels of water treatment before distribution for consumption. Changes in precipitation patterns and the higher temperatures projected could also impact the availability of water and create water supply shortages because of droughts and evaporation. The latter stressor could also increase the demand of water for cooling. The Department of Natural and Environmental Resources has initiated discussions with the U.S. Geological Services Caribbean Water Science Center to develop a network of water monitoring stations to specifically detect, monitor, and assess salt water intrusion and potential impacts on ground water resources in Puerto Rico.

[18] UNESCO, The United Nations World Water Development Report 2 (2006)

[19] UN Environment Programme Global Environment Monitoring System (GEMS)/Water Programme. (2008) Water Quality for Ecosystem and Human Health, 2nd Edition.

Box 1: POSSIBLE IMPACTS OF CLIMATE CHANGE ON PUERTO RICO'S AGRICULTURAL WATER RESOURCES BY ERIC W. HARMSEN

The Intergovernmental Panel on Climate Change (IPCC) has recently reported that in the future the Caribbean Region will receive less annual rainfall, however, severe storms, which occur during the wet season, will become more intense. How might the combination of higher temperatures and changing rainfall patterns affect Puerto Rico's agriculture? Here is what we might expect: Rising temperatures will increase heat stress in livestock and crops, which will reduce agricultural production. With increasing evapotranspiration (evaporation from soil and transpiration from plant leaves) during drier months, crop water requirements will increase, therefore the agricultural sector's demand for water will increase. If Puerto Rico's population continues to rise, competition for water and land will become more intense between agriculture and the other sectors of society. Drier soils will result in less annual surface runoff needed to fill our reservoirs and less annual aquifer recharge. A reduction in aquifer recharge will cause water tables to drop and may result in saltwater intrusion along the coasts, a problem which will be exacerbated by rising sea levels. With higher temperatures and drier conditions, soils may lose organic matter, which is essential to healthy agricultural systems. Climate change may adversely affect organisms which play important roles within the plant/soil/water system, for example, soil bacteria, which mediate many chemical reactions in the soil, and bees, which pollinate many agriculture plants.

The majority of soil erosion occurs during severe storms, therefore, with more intense tropical storms during the wet season, additional soil erosion can be expected, which will reduce surface water quality and contribute to the loss of storage space in our reservoirs. Flooding may increase, resulting in the loss of crops, and sea level rise may eliminate some of the agricultural land along the coasts, causing the affected populations to migrate to the higher elevations or urban areas. The loss of this land will result in a direct loss of agricultural production.

These threats to Puerto Rico's agriculture must be viewed within the bleak context of today's current situation. It is estimated that today greater than 75 percent of the Puerto Rican diet comes from imported food, and should the imports cease for any reason, the island has only a fifteen day food supply. Per capita food production continues to decline and farm land continues to be lost to the development of residential urbanizations and other non-agricultural uses. Puerto Rico's Agricultural Reserves, set-aside areas devoted to agricultural activities, continue to be under-utilized.

The future agriculture of Puerto Rico described above will exist within a society which is also suffering the adverse effects of climate change. As one example, Dr. Parham of the Caribbean Agriculture and Research Development Institute (CARDI) has described how tourism may be affected negatively because the Caribbean region may not be a desirable vacation destination in the future. People may not want to vacation here because of coastal erosion, coral bleaching, fear because of more frequent natural disasters, and higher temperatures causing vacation activities, for example hiking, to become less attractive. Warmer temperatures may also result in new pests and diseases in the region. A reduction in tourism would result in reduced agricultural sales to the tourist and hotel industry.

In a recent study conducted at the University of Puerto Rico, crop water requirements were predicted for the next 100 years for three locations in western Puerto Rico. The findings were consistent with the recently released report by the IPCC on global climate change, predicting that September will have excess water for plant growth, but during every other month of the year rainfall will be insufficient to meet plant water requirements.

The implications of these results suggest that additional water might be saved during the wet month(s), which could then be used to offset increased irrigation requirements during other months. The storage of additional water would require the construction of additional reservoirs in the mountainous regions of the island. Improving farm water use efficiency may also help to alleviate the problem of water shortages in the future. Educational programs should be directed towards farmers to assist them to manage their irrigation water more efficiently. Developing plant varieties which have higher tolerance for drought conditions is another way to prepare for the future. At the University of Puerto Rico, for example, we are studying different varieties of common beans and their response to drought stress. We hope that the study will lead to bean varieties which are more drought-tolerant. Development of drought resistant varieties of common bean is important since it is a staple in many poor countries.

Figure. Victor H. Ramirez, graduate student in Agronomy at UPRM, is describes a drought tolerance study of common beans currently being conducted at the UPR Agricultural Experiment Station at Juana Diaz.

Waste Water and Storm Water

Understandably, the design and magnitude of the Commonwealth's stormwater and wastewater systems varies greatly depending on location and the features of the communities served. For more detailed assessments, municipalities and agencies should look into their specific systems. Stormwater and watewater infrastructure systems have many components, including:

- Collection and transmission structures – gutters, pipes, streets, channels, swales, urban creeks and streams, and pumps;
- Quanity-control structures – ponds, urban lakes and infiltration devices and roof tops;
- Quality-control structures (e.g., grit chambers);
- Storage structures;
- Overflow systems for carrying both waste and stormwater;
- Water treatment facilities; and
- Discharge systems for the release of treated water.

The infrastructure will vary depending on whether it entails: (1) a combined system carrying wastewater and stormwater together in the same system; (2) a fully separated system carrying wastewater and stormwater in separate systems; or (3) a partially separated system with some divided wastewater and stormwater flows.

Present configurations can affect the degree to which climate change will impact stormwater and wastewater infrastructure. Climate changes could alter rainfall events, their annual volume, frequency and intensity. All of these factors might place added demands on collection and treatment systems (Engineers 2008).

Temperature changes are other influencing factors on wastewater and stormwater infrastructure. Warmer weather could decrease base flows and affect odor in discharge processes. During drier periods, dry soil could increase the possibility of pipe failures. Higher water temperatures could intensify pollution and adversely affect ecosystems, human populations and the reliability and cost of the collection and treatment systems. Changing conditions that affect the performance or cause failure to wastewater and stormwater systems represent a threat not only to the infrastructure itself but also to human health and safety, the economy, and the environment.

Waste water infrastructure in particular deals with used water management and treatment. Waste water infrastructure includes, but is not limited to pipe systems and waste water treatment plants. Flooding from sea level rise could cause structural damage to water treatment plants located in the coastal zone.

Storm water infrastructure, on the other hand, includes, but is not limited to, the system of pipes and channels that collect rainwater and divert it to the ocean or store it for detainment. Flooding from sea level rise could render existing storm water discharge pipes useless because these systems work by taking advantage of gravity (figure 4). Discharge areas would have to be adapted through the use of pumps. In addition, changes in precipitation patterns could negatively affect storm water infrastructure, if larger amounts of water need to be diverted and/or stored.

One wastewater treatment plant in San Juan is more critical than all others (WPI 2011). The San Juan treatment plant is the largest capable of treating up to 150 million gallons per day (mgd) of wastewater; the average rate is about 75 mgd. The excess capability is for times of heavy rains. During an extreme storm or tsunami the wastewater will most likely exceed 150 mgd of wastewater. In such an event, wastewater could potentially spill out into the streets and beaches of San Juan. Treatment plants in Puerto Rico are usually located in flood zones because these zones are at the lowest elevations, and the plants rely on gravity. These plants are built to withstand flooding by having the pit walls of the plants raised. The stations are sealed off so that they are capable of operating during flooding and the plants themselves are capable of running for 8-10 hours on reserve generators. These generators must be refueled after such a reserve event and if a large storm impedes access to roadways leading to the plants it will also prevent the refueling of the generators.

Of the 65 waste water treatment plants (WWTPs) that are located in Puerto Rico, only 17 are situated along the coast. WPI found that three plants are specifically vulnerable to sea level rise and storm surge. These plants are the Arecibo Regional WWTP, La Parguera WWTP, and the Boqueron plant at Villa Taina (WPI 2011).

Figure 5 Gravity stormwater drainage under average tidal conditions, with sea level rise, and when combined with extreme precipitation events. (Photos 1 and 2 courtesy of the Broward County Government, Florida)

According to the WPI study, PRASA reported no future plans to address climate changes and they do not currently budget for future scenarios past 50 years. The WPI study also found:

The total length of aqueducts within the coastal region of Puerto Rico is 1,095,712 meters. Of these, 208,632 meters (~18%) are susceptible to flooding caused directly from tsunamis. Of those that are located in FEMA flood zones, 47,074 meters are in the 0.2% annual chance flood hazard, 16,638 meters are in flood zone A, 252,666 meters are in flood zone AE, 203 meters are in flood zone AH, 7,974.46 meters are in AO, and finally 44,529.97 meters are located in flood zone VE.

Dams, Levees and Flood Control

The PRCCC was unable to find experts on climate change and Puerto Rico's dams and levees in regards to flood control and thus this should be a priority topic for future climate change vulnerability assessments. It can be assumed that current dams, levees and flood control structures might not be structurally suited to handle larger levels of water due to increased precipitation, and would be at risk of failure. Particularly when combined with sedimentation from poor soil and watershed management practices reducing dam capacity.

Box 2: Climate Change and Health Impacts in Puerto Rico

Climate change increases the vulnerability of Puerto Rico's population by affecting health and increasing mortality and morbidity. The age groups at high risk, such as the elderly and children, are not prepared to withstand higher temperatures or to face a higher thermal gradient (drastic changes in temperature). Added temperatures from global warming to urban heat islands, like San Juan, could add 15°F to normal temperatures. In Puerto Rico, extreme high temperatures have been recorded more frequently than ever before.

We can associate a higher incidence of respiratory diseases and skin cancer to conditions of global change. The increased incidence of asthma, skin cancer and a higher prevalence of cataracts in the population could be related to the effects of climate change. Already, the amount of ozone in our troposphere combined with a greater amount of particulate dust from the Sahara desert and Le Soufriere volcanic ash coming from the island of Montserrat, among other pollutants has increased the number of cases of respiratory ailments. The prevalence of the following diseases may directly be altered in Puerto Rico by climate change: dengue, malaria, malaria, ciguatera, Lyme disease, viral encephalitis, cholera, salmonellosis, E. coli, meningitis, asthma, bronchitis, pneumonia, skin cancer, cataracts and loss of immune system. More studies are needed to determine likelihood of changes in disease prevalence.

Ultraviolet radiation affects the health of Puerto Ricans to provoke a necessary adaptation to sun exposure. Currently we need preventive measures such as sunglasses with UV protection, hats and limit exposure to sun to a couple of hours. If we increased our exposure we risk increasing the occurrence of skin cancer, loss of vision and even effects on the immune and nervous systems. The increased number of cases with these conditions in Puerto Rico shows that the population is not aware or not interested in taking preventative measures to reduce the risks associated with excessive exposure to UV rays.

As the PRCCC WG 1 report states, extreme temperatures and rainfall, heat waves, floods and droughts will be on the rise. These extreme changes have a direct effect on mortality and morbidity. Moreover, climate change also exerts its effects on biodiversity and the ecosystem in general, which also impacts health. Water resources and food are being reduced as a result of pollution and the effect of extreme catastrophic events. In the past, Puerto Rico has been impacted by shortages of basic food and water during the passage of extreme events such as Hurricane Hugo (1989) and George (1998). Currently our water system is quite fragile, where erosion and sedimentation affects water quality during any period of rain or drought. At this moment we are very vulnerable to extreme events and our population at risk increases because we have created very fragile and unstable environmental conditions. For example, currently Puerto Rico has more flood-prone areas than ever before because we have altered natural drainage of storm water, particularly in our cities. Food quality has declined, not only by a change of diet, but because they are imported and thus go through cycles of freezing and cooling. The use of preservatives and chemicals in food production has also decreased its quality.

Climate change is also anticipated to affect medical services as insurance companies would have a greater number of claims and service delivery. This would disrupt the way policies are implemented and their costs.

Population-related vulnerability for Puerto Rico at a glance

General[2], [3] :

- 3.8 million Individuals; **27.5**% ≤19 years**,** 14.1 % ≥over 65.
- Population density 1,115m2
- Coastal zone population 2.73 million (70%)
- Population below poverty level 45% (vs. 15.1% for US)
- 68 hospitals (fiscal year 2001–2002); only 25 (37%) in the Metropolitan Region.
- No centralized medical care system.

Climate sensitive conditions[3]:

- *Cardiovascular* disease leading cause of death,
- *Asthma[4], [5]*. Rate is 113% higher than non-Hispanic whites and 50% higher than non-Hispanic black. The *Preva*lence and mortality of asthma attack is highest among Puerto Ricans and up to 41.3% in children
- *Hypertension, diabetes* and *asthma* comprise 46% of demand for health services *Anxiety/ depression* comprises 11.6% of demand for health services in women.

Potential affect of climate change on human health and Puerto Rico's vulnerabilities in the context of the IPCC Fourth Assessment Report (2007) and confidence levels:

1. **Altered seasonal distribution of some allergenic pollen species (IPCC[1]: high confidence)**

a. Puerto Rico: most aeroallergens are fungal spores[7]; no proven effect of carbon dioxide in spore's allergenicity. Increased wind speed and humidity (hurricanes/storms) may enhance spore spread. Thunderstorms and asthma exacerbations have been correlated with a doubling of ambient fungal spores[8].

2. **Increased heat wave-related deaths (IPCC[1]: medium confidence)**

a. No trends recorded in Puerto Rico in relationship to climate change. Urban heat island: temperature in San Juan increased at a rate of .06oC /year for the last 40 years[9] . It is predicted that the heat island effect can go up as high as 8oC by 2050.

3. **Increased malnutrition and consequent disorders, including those relating to child growth and development (IPCC[1]: high confidence)**

a. Vulnerability not assessed but 45% of population under national poverty level. Sociopolitical relation with the U.S. may ameliorate impact.

4. **Altered the distribution of *some* infectious disease vectors (IPCC[1]: medium/high confidence)**

a. No published data to support change in incidence of ciguatera disease, vibrio or dengue[6] infection.

b. No West Nile Virus or SL encephalitis reported so far (CDC).

5. **Increased burden of diarrheal diseases (IPCC[1]: medium confidence)**

a. Water quality (EPA 2003): 40% bodies of water do not meet quality standards primarily due to discharge sewage and agro/industrial contamination[3]. Diseases outbreaks related to interruption of water services or contamination. Outbreaks reported[10] but incidence limited; not a significant source of morbidity /mortality during natural disasters (e.g. hurricanes).

6. **Increase cardio-respiratory morbidity/mortality associated with ground-level ozone (IPCC[1]:high confidence)**

a. Asthma[4,5]. Rate in Puerto Ricans is 113% higher than non-Hispanic whites and 50% higher than non-Hispanic black. Also higher incidence of asthma attacks and mortality compared to other ethnic groups, representing a major source of morbidity as air quality changes.

b. High incidence and highest cause of mortality due to cardiovascular disease. Expected increase in ground level ozone, resulting from increased temperatures and pollution, may increase mortality associated to cardiovascular diseases[12].

7. **Increased number of people suffering from death, disease and injury from: heat waves, floods, storms, fires and droughts (IPCC[1]: high confidence).**

a. Hurricanes in Puerto Rico can be a source of morbidity, mortality and psychological stress (population displacement). Example:

i. Hurricane Georges[11]: Three direct deaths; nine indirect. (heart attacks, etc.). Power and water out to 80% of the 3.8 million people on island. 33,113 homes destroyed in Puerto Rico, with nearly 50,000 more suffering major or minor damage.

ii. Hurricane Hugo[13]: 2 direct fatalities, 22 indirect. Water services in the San Juan area were disrupted for 9 days. More than 200,000 families affected with homes destroyed or damaged. Tank trucks used temporarily to distribute water from elsewhere on Puerto Rico.

8. **Psychological/psychiatric effects of climate change (not included in IPCC 2007 assessment).**

a. Major source of morbidity and potentially mortality for ***all*** populations. Percent of adults reporting limited activities due to physical, mental or emotional disorders in 2009 was 17.30%[14].

b. Mental health care is not structured or coordinated and has deteriorated since implementation of the new health reform[15].

1. http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch8.html)
2. http://www.census.gov/compendia/statab/cats/puerto_rico_the_island_areas.html
3. http://www.paho.org/HIA/archivosvol2/paisesing/Puerto%20Rico%20English.pdf)
4. http://www.lung.org/assets/documents/publications/solddc-chapters/asthma
5. http://www.epa.gov/asthma/pdfs/asthma_fact_sheet_en.pdf
6. PLoS Negl Trop Dis 3(2); e382.doi:101371 2009
7. Int Arch Allergy Immunol 2011;155:322–334
8. Allergy. 2010. 65(9):1073-1081
9. http://nargeo.geo.uni.lodz.pl/~icuc5/text/P_6_14.pdf
10. http://www.cdc.gov/mmwr/preview/mmwrhtml/ss6012a4.htm?s_cid=ss6012a4_w
11. http://www.ncdc.noaa.gov/oa/reports/georges/georges.html
12. http://aje.oxfordjournals.org/content/154/9/817.full
13. http://www.nws.noaa.gov/om/assessments/pdfs/hugo1.pdf
14. http://www.cdc.gov/mmwr/preview/mmwrhtml/ss6009a1.htm
15. J Psychiatr Pract. 2010 Mar;16(2):129-37

Economic Development

A Brief Overview of Puerto Rico's Economy

In the past six decades there has been a major shift in the foundation of Puerto Rico's economy. Historically, Puerto Rico was an agricultural economy, based on sugar, tobacco, and coffee products. During that time manufacturing was a relevant but much smaller sector of the economy. Currently Puerto Rico's modern economy is oriented to industry and services. This major shift can be seen when comparing a 1940's economy to that of 2002 where agriculture went for being over one third of the total net income in 1940 to only 1% in 2002. Additionally, commercial fishing has historically been a component of the agricultural sector (with the Puerto Rico Department of Agriculture providing support to commercial fishers). Fishery statistics indicate fishery resources are declining in abundance around Puerto Rico as evidenced by a 69% decrease in the number of pounds landed between 1979 and 1990. Possible causes: (1) declining catch per unit effort; (2) marketing of species that previously had no commercial value; (3) large proportion of harvest made up of sexually immature individuals; and (4) the change to more generalist gear such as nets (CFMC 2004). In 1931, a total of 1,403 active commercial fishers were reported compared with 1,758 in 1996 and 1,163 in 2002 (Matos-Caraballo 2004). Today, approximately one quarter of commercial fishers hold a second job, usually as seasonal construction workers but occasionally as clerks or factory workers (CODREMAR 1986; CFMC 2004). Further adding to the evolving modern economy, in 1940 manufacturing represented 12.8% of the economy while in 2002 it jumped to a dominant 45.7% and in 2010 was 46%. Second to manufacturing, the financial sector today is 19% of GDP. This sector includes banking, insurance, and real estate. (Due to data limitations the financial sector is not assessed in this report as related to climate change. The Puerto Rico Coastal Zone Management Program is commissioning a study on the Puerto Rico insurance industry for 2012-2013 and the PRCCC recommends future assessments include the financial sector in detail.)

Changes within the economic sectors have also occurred, as in the case of manufacturing. At first, this sector was a heavily labor intensive industry, due to the government-launched industrialization program known as "Operation Bootstrap", which began in 1948. Under this program the island became industrialized by providing labor locally, inviting investment of external capital, importing raw materials, and exporting the finished products to the U.S. market. To entice participation, tax exemptions and differential rental rates for industrial buildings were offered. As a result, Puerto Rico's economy shifted labor from agriculture to the manufacturing of food, tobacco, leather, and apparel products. In the last four decades, due to structural and technological advances, the sector has changed to capital and knowledge intensive industries such as pharmaceuticals, chemicals, machinery, electronics, and biotechnology. In these types of capital-intensive industries the amount of capital involved is much higher than the proportion of labor. The industrial structure and industry type require high value investments in capital assets. Another factor in Puerto Rico's evolving economy is its human capital. The population of Puerto Rico has access to local, affordable, high quality education, and many, perhaps a majority of institutions (and, as a result, their graduates) are bilingual, providing further incentive for the shift to capital and knowledge intensive industries.

An important economic consideration is that Puerto Rico has fiscal autonomy with regards to the United States due to the Commonwealth status, which implies that Puerto Rico residents do not pay federal income taxes (unless income comes directly from the Federal government; though they do pay into social security) and the local authorities have discretion to design tax incentives to attract foreign direct investment. Due to its fiscal autonomy several Puerto Rican administrations have been able to develop the manufacturing and services sectors of the economy in a short period of time. Further aiding Puerto Rico's economy are its extensive highways, ports, airports and modern communication systems allowing for an efficient transport of goods throughout and beyond the Island.

These factors illustrate how the private sector with assistance from the public sector developed today's economy, as according to GDP, in Puerto Rico to be dominated by manufacturing and as such an economic leader in the Caribbean and Small Island Developing States (SIDS) around the world. Out of 228 countries world-wide, six of the SIDS have GDPs in the top half relative to all 228 countries. These are Singapore, Cuba, the Dominican Republic, Puerto Rico, Bahrain and Trinidad and Tobago. Relative to their GDPs, 88% of the SIDS have GDPs that rank in the bottom half when compared to the rest of the world (CIA World Fact Book 2010). This fact makes Puerto Rico (ranked 83 worldwide and ranked 4th when compared to the SIDS) one of the wealthiest and most financially competitive SIDS in the world. In addition, Puerto Rico ranks 47th in terms of world export and 57th in terms of imports. Seen differently, compared to the other SIDS, Puerto Rico ranks 4th in terms of GDP, second to Singapore in terms of exports and imports. Compared to the other 14 colonial/territorial SIDS world-wide (American Samoa, Anguilla, Aruba, British Virgin Islands, Commonwealth of Northern Marianas, Cook Islands, French Polynesia, Guam, Montserrat, Netherlands Antilles, New Caledonia, Niue, and the U.S. Virgin Islands) Puerto Rico has the highest GDP, export, and import ranking. The two closest are the U.S. Virgin Islands and the Netherlands Antilles.

The economic indicators in Tables 2 and 3 reflect that the modern day economy of Puerto Rico are divided into a couple of major sectors, but these sectors are not where the majority of the labor force works. The two sectors that dominate the economy in terms of GDP are (1) manufacturing and (2) finance, insurance and real estate, making up 66% of Puerto Rico's GDP combined. However, together they only employ 12.9% of the labor force. In contrast, 75.4% of the labor force is employed in the services (such as tourism and hospitality), government and trade sectors which together amount to only 29.1% of Puerto Rico's GDP. Thus, it is important to consider more than just GDP when assessing the vulnerabilities of Puerto Rico's society and economy to potential climate changes.

Puerto Rico's Economy and Climate Change

In the face of climate change, several aspects of Puerto Rico's economy must be considered. Principally, Puerto Rico's economy and workforce are heavily concentrated in sectors that strongly depend on transportation systems and telecommunication services. These two types of infrastructure could be compromised during the projected more intense and frequent extreme weather events. Capital intensive industries that are dependent on their unique infrastructure are at risk of not recovering from the potential damage that more intense weather events can cause due to the large financial commitment that is typically required to get the first unit of good or service produced in those types of industries. In fact, 40% of businesses that are affected by natural or man-made disasters never reopen (Insurance Information Institute 2012).

40% of businesses that are affected by natural or man-made disasters never reopen

(Insurance Information Institute 2012)

Similar considerations regarding potential detrimental impacts to the proper functioning of critical infrastructure and services (power, water, ports, etc) are also of concern for the majority of the work force. Many of these concerns stem from the fact that Puerto Rico is an island with nine (9) major ports and harbors and eleven (11) airports that are vulnerable to intense weather events. The manufacturing, services and trade sectors all rely on the regular operation of critical transportation systems (highway, ports, airports).

Puerto Rico's main trading partners are not based in the region. As of 2010 Puerto Rico's main export partners were: the United States, with 68.1% of the share; Spain, with 19.5%; Germany, with 8.1%; the Netherlands, with 4.7%; and Belgium, with 3.7%. Major importing partners included: – the United States, with 51.2% of the share; Ireland, with 15.5%; Singapore, with 4.7%; Japan, with 4.3%; and the U.S. Virgin Islands, with 3.9% . This emphasizes Puerto Rico's reliance on transportation systems for the health of the Island's economy as well as brings attention to the global systemic problem of climate change. If climate changes in the regions of Puerto Rico's main trading partners affects those countries' production of products negatively Puerto Rico's imports could be affected. This theme will be touched on in this report, but an in-depth analysis on this specific topic is outside the scope of this PRCCC report.

[20] Data from Puerto Rico Planning Board (2010) and the U.S. Department of Commerce U.S. Commercial Service PR--USVI (2010, 2011, 2012).

The following figures give a summary of the Puerto Rican economy showing the composition by sector alongside the labor force by occupation as well as various economic indicators.

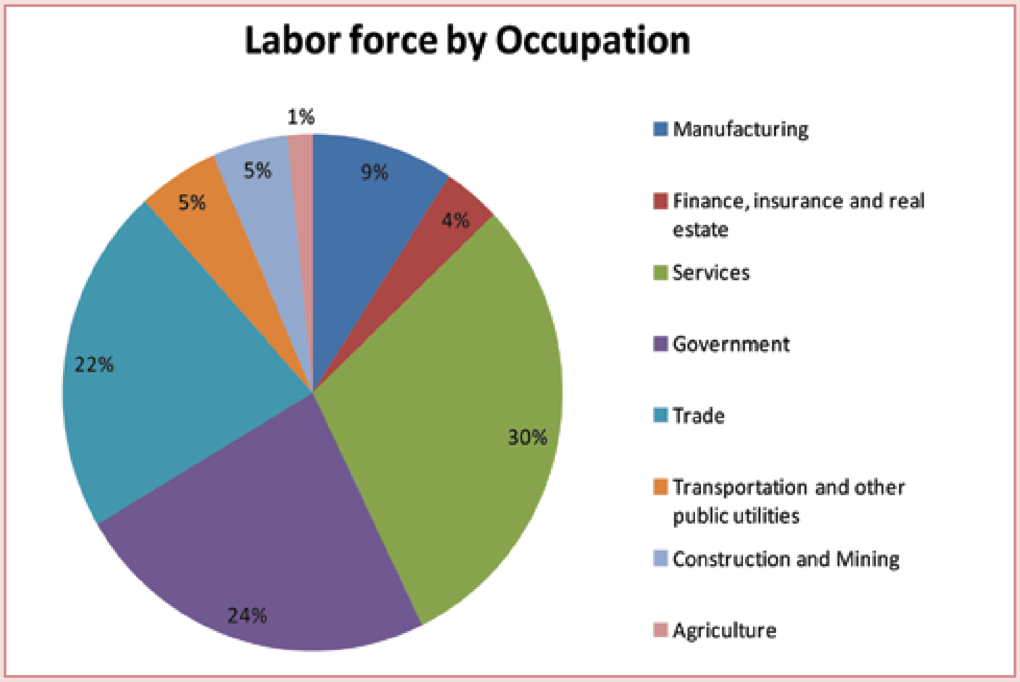


Figure 6: Puerto Rico Labor Force by Occupation. Source: Data from Government Development Bank for Puerto Rico factsheet, July 2011 (2010 data)

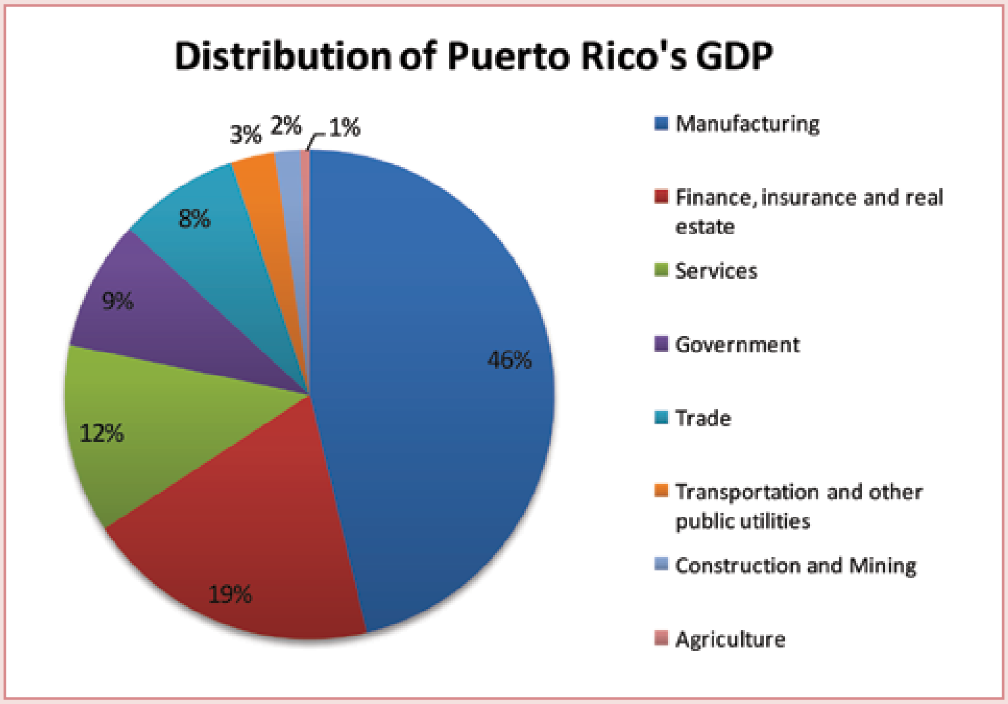


Figure 7: Distribution of Puerto Rico's Gross Domestic Profit (GDP) by sector. Source: Data from Government Development Bank for Puerto Rico factsheet, July 2011 (2010 data)

Area/Region of Puerto Rico	Unemployment Percentage as of July 2011
San Juan-Caguas-Guaynabo	15.4%
Ponce	16.3%
Fajardo	19.3%
Mayaguez	17.9%
Aguadilla-Isabela-San Sebastian	17.4%
San German-Cabo Rojo	16.1%
Yauco	18.7%

Federal funds also have an important role in the economy, as they impact personal consumption and public expenditures (funds for recurrent expenditures and construction investment). Their biggest impact, though, is on personal income and expenditures, as transfers to individuals (including Medicare and Social Security) represents, at least 67% of total receipts. Medicare and Social Security benefits account for 66% of the transfers to individuals. The next biggest item is the receipts from the Nutritional Assistance Program (PAN). They account for 12% of the total transfers to individuals as of fiscal 2009. The importance of these funds on public expenditures cannot be overestimated, as federal funds represent 23% of the total revenues of the government's consolidated budget. Federal Funds are an important source of revenue to individuals, and so to personal consumption. Total transfer payments to individuals represented 34% of personal income in 2009, from 30.2% in 2000 (in the U.S. the share is about 17%).

Population	3,791,913 (July 1, 2010 est.)
Labor Force	1.31 million (2010)
Population below poverty line	41.4% (2009)
Unemployment Rate	16% (2010)
GDP [GDP -per capita]	$96.3 billion [$24,229] (2010)

Of these, the share of transfer payments from the Federal Government (which includes Medicare, Social Security, PAN, and other grants) represent 22% of personal income and 65% of the total transfer payments.

Real Growth of Puerto Rico's Economy

Recent economic performance has distanced itself from the historic highs of the early 1970's. For the past decade (2000-2009) real growth averaged 0.1%, quite below that for the previous decade (2.7%). Moreover, since 2007 the economy has been going through a recessionary phase much more pronounced than that of the United States. More importantly, this latest contraction continued the local economy's long-term deceleration (see figure 8).

- **Federal Funds represent 27% of the Island's GNP.**
- **Federal Funds represent 23% of the total revenues of the Government's Consolidated Budget.**
- **Federal Transfer Payments represent 34% of personal income.**

Figure 8: Average annual growth of real GNP, 1970-2011 for Puerto Rico and the United States

According to data reported by the Puerto Rico Planning Board (PRPB), on April 20, 2012, real growth in fiscal 2011 was -1.5%, a contraction below the revised estimate for 2011 of -3.4%. In nominal terms, GDP was $64,106.2 million. For fiscal years 2012 and 2013, estimates are positive, a growth of 0.9% and 1.1%, respectively. However, these increases remain below the historical average. These growths are based on expected increases in personal consumption expenditures and investment in construction. Also, the gap between the growth of Puerto Rico and U.S. economies remains.

The challenge, in terms of recovery is still significant. Given than the projections of the PRPB for fiscal years 2012 and 2013 are on average 1.0%, and assuming an optimistic scenario, the economy needs to grow at an annual rate of 2.5% beginning in fiscal year 2014, to achieve in 2018 the real GNP of 2006 (figure 9).

Manufacturing Average Hourly Earning: $7.85

Manufacturing Average Weekly Earning: $310.86

Manufacturing accounts for 55.5% of GDP:

- **manufacturing of pharmaceuticals,**
- **chemicals,**
- **machinery,**
- **electronics,**
- **apparel,**
- **food products,**
- **instrument,**
- **textiles, and**
- **clothing.**

Figure 9: Needed GNP growth to reach 2006 levels, assuming an annual growth of 2.5% from 2014 to 2018.

Manufacturing

In the late 1940s, manufacturing was seen as the strategy that would allow Puerto Rico to develop economically, since political leaders of the time considered agricultural countries to be underdeveloped and associated industrialization with wealth. As a consequence, the government launched an industrialization program known as "Operation Bootstrap." Under this program the island was to become industrialized by providing labor locally, inviting investment of external capital, importing the raw materials, and exporting the finished products to the U.S. market. To entice participation, tax exemptions and differential rental rates for industrial buildings were offered. As a result, Puerto Rico's economy shifted labor from agriculture to manufacturing and tourism.

Over time, Puerto Rico's manufacturing sector has shifted from the original labor-intensive industries, such as the manufacturing of food, tobacco, leather, and apparel products, to more capital-intensive industries, such as pharmaceuticals, chemicals, machinery, and electronics. Puerto Rico's major manufacturing activities (listed in the order in which they contribute to the manufacturing domestic income) are: chemical and allied products; machinery and metal products; food and related products; apparel and related products; printing and publishing; leather and leather products; stone, clay, and glass products; tobacco, paper and allied products; and textile mill products. San Juan and Mayagüez are the leading centers for clothing production, mostly the manufacturing of uniforms through federal contracts with the United States.

Storms and hurricanes are a good way to test the entire system of manufacturing as related to climate change (Puerto Rico Manufacturer's Association, *personal communication,* July 17, 2012). Past events, specifically Hurricanes Hugo and Georges, disrupted transportation systems and thus disrupted many industries' operations greatly. However, there are few reports of atmospheric conditions causing structural damage to company infrastructure. Yet on a regular basis there are floods regionally in Puerto Rico and these events do disrupt industry production. Examples include, business being interrupted when workers are absent because their children's' schools are closed due to flooding. Or if workers are unable to reach the manufacturing plants due to impassable roads. Or if communication lines are down due to the majority of areas having above ground lines the company might lose business. Depending on the industry and its size the companies might be able to sustain two to three days of service interruption. Chances are higher of resistance to events if there is sufficient time to prepare. Some industries in Puerto Rico require specific equipment that cannot shut down without corrupting whole batches of raw materials and these businesses are more susceptible to being negatively affected by service interruptions. Furthermore, the ability of industry to ship their products off island is an important consideration. As previously mentioned, flooding events from sea level rise, storms, and heavy rains, might shut down air and seaports. Most products are flown out via airports and not seaports, like pacemakers and pills, however, certain items like alcoholic beverages from the rum distilleries or beer bottling plants cannot be exported via airports and rely on functioning sea ports.

"This will take some time. The problem is that time isn't something we have very much of, given the way climate change is accelerating, so we have to move very quickly."

~ Geannette Siberón, chairwoman of the Puerto Rico Manufacturer's Association Environment Committee

(2012 Environmental Awards, March 30th, 2012)

Currently there are no water quality or quantity restraints for the manufacturing industry, a plus for Puerto Rico in terms of economic competitiveness. Many companies have their own wells and are not connected to PRASA. An independent study is needed to determine how future droughts in the Caribbean will affect Puerto Rico's water resources and dependent industries, like manufacturing.

Adaptive capacity of Puerto Rico's manufacturing industry may be sufficient to deal with climate change as there is a functioning network for emergency management. This network may prove useful in the future as sites become more exposed to climate changes. The network right now mostly shares their inventory of supplies (e.g., nitrogen), helicopter landing sites, contact information, tents, etc and each firm is given the resources by the Puerto Rico Manufacturers' Association to develop emergency plans. However, this network, and therefore the industry's adaptive capacity, has not yet been tested by a large hurricane.

From the experience of past storm events it can be inferred that climate change may affect manufacturing indirectly, like human resource issues and service interruptions, and to a lesser extent from direct structural damages. This highly depends on the location of the industry facilities, their method of export (i.e., air versus sea), their connection to the network for emergency management, and the type of industry.

Box 3: Film and Entertainment Industry

The last few years Puerto Rico has promoted the film industry like never before, managing to put Puerto Rico on the map as a unique and attractive destination for film and television production. The film industry is one of the most important lines, not only for economic development, but for cultural development. This in turn influences other activities like the rental equipment and hotel industries, ultimately greatly impacting the consumption of goods. The filming, the core of the film industry, has the characteristics of a mass consumer product, also as an economic and cultural phenomenon, presents a great opportunity to advance jobs and economic development, especially with the competitive advantages of our island: our professional technicians, our localities, our world-renowned artists and actors, the natural and cultural resources of our beautiful island. The implications of climate change for tourism, natural resources, and the services industry could deter filmmakers from choosing Puerto Rico as a filming location. The following are just a few of the major films sahot in Puerto Rico:

- **Pirates of the Caribbean** ***filmed in Palomonitos Island off of Fajardo and Castillo de San Cristobal Fort in Old San Juan***
- **Fast Five** ***filmed in multiple urban areas of san Juan and Carolina***
- **Golden Eye (James Bond)** ***and*** **Contact** ***filmed in Arecibo Observatory***
- **Amistad** ***filmed in El Morro***
- **Che** ***filmed near a beach in Luquillo within the Northeast Ecological Corridor***
- **The Lord of the Flies** ***filmed in various locations like Aguadilla, El Yunque and Vieques***

Tourism

Small Island Developing States (SIDS) can be viewed as "Gardens of Eden", "luxurious vacation spots", or "sun and sand destinations" – in other words, tourism hotspots. Puerto Rico's rainforests, mangroves, and many miles of coast, provide beach, sand, and sun to tourists and residents alike. Indeed, tourism is a large part of Puerto Rico's economic well-being and is the leading segment in the service industries. It accounts for 7.0% of the gross domestic product and 6.7% of employment. In 2010-2011 Puerto Rico received 4,213,673 visitors, and tourist receipts reached 3.4 billion (Puerto Rico Toursim Company *personal communication* June 2012). According to the Planning Board tourism employs 65,304 people directly and indirectly. And tourism is on the rise. The total number of visitors in Puerto Rico increased from 4.6 million in 1999 to 4.9 million in 2010 (PRTC 2011). The number of tourists staying in hotels increased by 28% between 1999 and 2010. Total tourism-related employment increased from 30,225 in 1985 to 54,656 in 2010, or by a factor of 81%[1].

Climate not only determines the length and quality of the tourism season, it is also an important driver of tourism demand to some regions. Climate affects the natural environment in ways that can either attract or deter visitors. The economic drivers of tourism in Puerto Rico (i.e., beaches, coral reefs, mangroves, rainforests, etc.) are extremely vulnerable to climate change[2] and, as reflected in Table 4 and the PRCCC Working Group 2 report, all of these assets are threatened by climate change. Moreover, Puerto Rico has invested heavily in tourism-related infrastructure, most of which lies in the coastal zone.

An economic valuation study of coral reefs andassociated resources in eastern Puerto Rico, conducted by the Department of Natural and Environmental Resources in 2007, reported that the direct contribution of recreational activities and tourism to the Island's economy was of $ 939.8 million. A total of $747.7 million were in consumer spending: $340.3 million were direct consumer spending on beaches; en $589.7 millions in nautical activities; $2.7 millions were spent in diving and related activities and $3.9 millions kayaking.[3]

Additionally, a 2006 study of visitor use of El Yunque National Forest, conducted by the U.S. Forest Service, sheds light on what visitors are looking for in Puerto Rico's tropica montane settings. They found that most national forest visitors participate in several recreation activities during each visit. Hiking/walking (55%) and viewing scenery (20%) are the dominant primary activities. Those same activities are participated in by more than three-quarters of the visits to this forest. Nearly two-thirds spend time viewing wildlife. Other activities include driving for pleasure, relaxing, nature center activities, visiting historic sites, nature study, and picnicking.

Temperature

One of the main tourism assets of Puerto Rico is the Caribbean's predictable sunny and warm conditions, particularly during the winter in major market regions in North America and Europe. With changing climatic conditions, two potentially negative impacts are possible. First, Puerto Rico may become "too hot" for tourists during some seasons. Surveys of European tourists have revealed the optimal conditions for beach tourism of 27°–32°C, roughly 80°-90° F (Rutty and Scott 2010). As the number of months in this optimal climatic zone decline somewhat, Puerto Rico may become too hot during the summer for most tourists, although little impact in the peak winter tourism season is anticipated. What is more, hotter local temperatures, along with warmer winters

[22] Edwin A. Hernández- Delgado, Carlos E. Ramos-Scharrón, Carmen R. Guerrero-Pérez, Mary Ann Lucking, Ricardo Laureano, Pablo A. Méndez-Lázaro and Joel O. Meléndez-Díaz. 2011. Long-Term Impacts of Non-Sustainable Tourism and Urban Development in Small Tropical Islands Coastal Habitats in a Changing Climate: Lessons Learned from Puerto Rico. In "Visions for Global Tourism Industry – Creating and Sustaining Competitive Strategies".

23 See the on-line documents from the May 8-10, 2007 roundtable of experts "Facing the Consequences of Climate Change in Puerto Rico," organized by The University of Puerto Rico at Mayagüez (UPRM): http://academic.uprm.edu/abe/ClimateChangePR

24 Economic Valuation of Coral Reefs and associated resources in Eastern Puerto Rico: Fajardo, Arrecifes La Cordillera, Vieques and Culebra. (2007). Prepared by Estudios Técnicos, Inc. for the Department of Natural and Environmental Resources. .

in northern latitudes may eventually reduce the number of tourist visits, especially when combined with decreasing beach aesthetics as erosion from sea level rise increases and safety concerns the destructive forces of stronger hurricanes, ocean surges and heavy rains.

The second negative impact is related to the temperature in those countries from which tourists mostly come from. As temperatures increase, demand for winter getaway holidays is anticipated to decline, though the extent of this has not yet been quantified. Similarly, if climatic conditions in other destinations, like the Mediterranean, for instance, improve sufficiently, they may become more competitive with the Caribbean. The warming of other regions could represent new competition for tourists during the fall and spring seasons or even during winter seasons in the northern hemisphere. For example, new competition could come from Southeastern U.S. locations such as Myrtle Beach, South Carolina, Savannah, Georgia, or the Alabama-Mississippi Gulf Coast.

Climate Stressor	Implications for Tourism
Warmer temperatures	Altered seasonality Heat stress for tourists Increased cooling costs Changes in plant-wildlife-insect populations and distribution range Health impacts such as infectious and vector-borne disease ranges
Increasing frequency and intensity of extreme storms	Risk for tourism facilities Increased insurance costs/loss of insurability Business interruption costs
Reduced precipitation and increased evaporation in some regions	Water shortages Competition over water between tourism and other sectors Desertification Increased wildfires threatening infrastructure and affecting demand
Increased frequency of heavy precipitation	Flooding damage to historic architectural and cultural assets Damage to tourism infrastructure Altered seasonality (beaches, biodiversity, river flow)
Sea Level Rise	Coastal erosion Loss of beach area Higher costs to protect and maintain waterfronts and sea defenses
Sea Surface Temperature Rise	Increased coral bleaching Marine resource aesthetic degradation in dive and snorkel destinations
Changes in terrestrial and marine biodiversity	Loss of natural attractions and species from destinations Higher risk of diseases in tropical-subtropical countries
More-frequent and larger forest fires	Loss of natural attractions Increase of flooding risk Damage to tourism infrastructure
Soil changes (moisture levels, erosion, acidity)	Loss of archaeological assets and other natural resources, with impacts on destination attractions and agriculture

Table 4 Source: Adapted from Simpson et al. 2011 and UNWTO-UNEP-WMO, *Climate Change and Tourism: Responding to Global Challenges* (Madrid: 2008).

Sea Level Rise

A rise in sea level would negatively affect the tourism sector of Puerto Rico since it would most likely imply a loss of beaches. Importantly, Puerto Rico beaches are already suffering from heavy beach erosion due to poor coastal management (sand extraction, jettys, poorly planned marinas, etc.). Increased and more severe beach erosion from the combined effects of existing vulnerabilities and the expected climate stressors could affect hotel properties that are located in the coast. Beach erosion could even compromise the integrity of existing buildings. Like permanent residents, tourists would be affected by any impact that the rise in sea levels may have on the existing infrastructure, including utilities, roads and transit, and recreational and leisure facilities (parks, boardwalks, meeting venues, etc.)

In order to differentiate Puerto Rico from other "sun and sand" destinations in the Caribbean the Puerto Rico Tourism Company has promoted other tourism niches. One of these is the "Urban Tourism" market. There has been considerable public investment in recent years from the Commonwealth and municipal governments to turn the San Juan Metropolitan Area into an "Urban Tourism" attraction. Examples of this emphasis are the re-vitalization efforts in Condado and Isla Verde, the Coliseum of Puerto Rico, and the development of the Puerto Rico Convention Center District in Isla Grande. Other efforts that are in the planning stages or in early construction are the *Bahía Urbana* and the *San Juan Walkable City* program both on the San Juan Islet. All of these urban revitalization efforts are on or near the coast and, depending on the rate of sea level rise, might be at risk. Adaptation and mitigation efforts would be needed in order to protect these investments.

Tropical Storms and Tourism

Some models predict that climate change phenomena may increase the frequency and intensity of tropical storms in the Caribbean Basin. Anecdotal evidence shows that there is a correlation between the impacts of storms in localities in the Caribbean and a lower flow of tourists to those localities. This lower flow of tourists seems to last for about a year to two years.

One example of this trend was seen in the "Mayan Riviera"[1] in the aftermath of Hurricane Wilma (2005)[2]. Another example is Grand Cayman in the aftermath of Hurricane Ivan (Category 5; September 12, 2004). Regarding Ivan's impact on the Grand Cayman Island, Governor Bruce Dinwiddy described the damage as "very, very severe and widespread." Despite strict building codes that made the islands' buildings well able to withstand even major hurricanes, Ivan's winds and storm surge were so strong that a quarter or more of the buildings on the islands were reported to be uninhabitable, with 85% damaged to some extent. Much of Grand Cayman still remained without power, water, or sewer services for several months later. After five months, barely half the pre-Ivan hotel rooms were usable.[3]

Decreased Precipitation and Tourism

Some models predict that climate change will lower the rate of precipitation in Puerto Rico while other models say that the precipitation levels will increase. Should the latter be correct, Puerto Rico could expect more flooding events. Also, with changes in rainfall a sustained increase in the average number of rainy days per year might impact occupancy of hotels, particularly from local residents. During 2010-2011, the increase

25 Cancún, Cozumel, and Playa del Carmen
26 http://en.wikipedia.org/wiki/Hurricane_Wilma (retrieved on Sept. 23, 2011)
27 http://en.wikipedia.org/wiki/Hurricane_Ivan#cite_note--WMO_2004_summary--16 (retrieved on Sept. 23, 2011)

in rainy days had a recorded negative impact, according to the Puerto Rico Tourism Company.

Flooding and Tourism

Flooding is likely to impact tourism infrastructure dramatically. Recently, the Office of Planning and Development of the Puerto Rico Tourism Company conducted a flood risk analysis for endorsed lodgings in Puerto Rico. This analysis was done using the Flood Zone ArcGIS shapefile provided by the Puerto Rico Planning Board and the PRTC's endorsed lodging location shapefile. According to this study, Puerto Rico has an inventory of 14,306[4] endorsed rooms. , 4,984 (34.8%) of which are currently in a high risk flood zone (1% chance of flooding or greater). Importantly, a significant percentage of room inventory would be negatively affected by increases in tropical cyclone events. According to this PRTC study, 3,080 endorsed rooms (21.5%) are in the VE flood zone, which is a zone at particular risk of storm surges.

Outdoor Recreation

Many of the people that participate in outdoor recreational activities are not aware of the economic and social importance of recreation and its relationship to natural resources and natural attractions. Recreation consists of activities or experiences conducted during leisure time, voluntarily chosen by the participant for purposes of relaxation, entertainment, or social or personal development. Outdoor recreation includes all of those recreational activities that cannot necessarily be practiced indoors, such as marine recreation, which involves use of coastal and marine resources as attractions by individuals or social groups. Recent studies show that we derive the greatest satisfaction from participating in outdoor recreational activities, while at the same time sharing experiences with family and friends. Other factors that make enjoyment of the outdoors particularly rewarding include: contact with nature, the opportunity to improve physical and mental health, tranquility and enjoyment of the natural scenery.

The recreational opportunities offered by a destination are the drivers of tourism. Theyattract people from abroad, usually to spend their free time enjoying the sights, visiting friends or relatives, appreciating the environment, or taking part in sports or other recreational activities. Accordingly, Puerto Rico's outdoor recreation and tourism industries both depend on the health and continued viability of our beaches, rivers, mountains, wetlands, coral reefs, mangroves, fisheries, flora and fauna, geological formations, historical resources, valleys and coastal lagoons.

Recreational fishing is an important component of tourism both for locals and tourists. Alternatives include the use of charter fishing for offshore species like tuna or dorado and coastal lagoons for species such as snook and tarpon fishing as much as the shore. Several yacht clubs in Puerto Rico organize tournaments for fishing of various species. In addition to tourism activities, many people in Puerto Rico practice the sport of recreational fishing. A study of recreational fishing in Puerto Rico and the U.S. Virgin Islands found that recreational fishing on the high seas (more than 3 miles offshore) followed by fishing from the shore was very common around the island (Griffith et al. 1998; DNER 2000).

The government of Puerto Rico directly receives a large amount of revenue generated by tourism and recreation. This revenue is generated in part by the Port Authority through the collection of feeds for the use of facilities by cruise ships and

28 As informed by the PRTC's Touristic Products and Services Division, May 2011. This figure only includes the rooms and lodgings that receive tax exemption and investment incentives and that meet the standards of quality as defined by the PRTC's *Minimum Requisites for Lodging Facilities Regulation*. This does not include the whole room inventory of the island.

the granting of landing permissions and rights for both airlines and cruise ships to re-fuel and transport passengers in Puerto Rico. Tourists generate considerable local income from their use of slot machines at beach resorts and hotels. Overall, tourism spending in Puerto Rico is more than $2 billion per year and the total indirect and direct employment induced by tourism exceeds 50,000 jobs. As tourists, recreationists spend on travel, food services, specialist equipment for the practice of recreational activities, and accommodations for overnight camping, hotels, and inns.

In 2007, the economic impact of the Puerto Rico National Parks System was estimated. During that year, the parks received 3.5 million of visitors. The National Parks Company generated a total of 645 direct jobs and $24,209,108 in payroll.On the other hand, visitor spending generated a total of $ 12,154,675 in direct revenues for the agency and $ 15,705,308 in purchases of goods and services. The total impact on the economy was estimated at $95 million in production, 1.233 direct jobs, indirect and induced, $ 32 million in direct wages, indirect and induced effects and $ 5.7 million in tax revenue. 80% of the economic impact occurs in the economic regions and municipalities where the facilities are located.[5]

The scientific data clearly indicates that there are certain aspects related to climate change that currently affect and threaten the natural resources and attractions that serve as the foundation for most leisure activities practiced outdoors in the archipelago of Puerto Rico. Stressors related to climate change include: sea level rise, rapid variations between periods of drought and floods, increases in average temperatures, and a marked drop in average annual rainfall.

Thus, climate change is predicted to have critical negative impacts to our very natural resources and attractions that serve as the foundation of our outdoor recreation and tourism industries.

Flooding from Sea Level Rise and Precipitation

Among the most evident impacts expected from the projected sea level rise associated with climate change is loss of beaches due to the processes of erosion. This will represent an enormous challenge for Puerto Rico because of the extreme high costs associated with the transport of sand in order to form new beaches.

We are also losing wetlands, lagoons, and coastal valleys due to inundations, which in turn are affecting flora and fauna and the continued viability of activities such as fishing, hunting, hiking and bird watching. In addition, intense rain will provoke flooding in coastal communities and buildings close to the coast. Increased flooding will likely cause increased sedimentation in our bodies of water.

Temperature

The increase in average temperatures may limit the amount of time individuals can practice outdoor recreational activities, causes changes in the clothing required, and increase reliance on other products to protect from heat and sun. This will ultimately alter attitudes about spending time outdoors. This is of great importance as climate change will likely extend the summer season and shorten winter in northern countries, reducing the number of tourists who visit the Caribbean and Puerto Rico to escape the cold weather (i.e., shorter tourist season). Furthermore, the increase in average temperatures will affect corals and, consequently, regional fisheries. This will have a negative impact on the diving industry, recreational fishing, and the food industry. Finally, expected droughts might reduce aesthetic attraction to portions of the landscape as scenic, vegetated areas such as forests, mountain views, and pastureland lose their greenery. A rise in sea temperatures may also affect the habitats of marine species including important species for recreational fishing like snook and tarpon, among others. In addition, some increases in sea temperature may cause the distribution of plankton to change, causing the distribution of plankton-eating species to change in response. One study found that the distribution of wild salmon was changing due to a change in plankton distribution caused by increasing temperature in the North Atlantic (Kinitisch 2006).

Finance

There are currently eighteen commercial banks in Puerto Rico, most of them local corporations. Local banking institutions include: Banco Popular, the largest banking institution, with over one hundred branches throughout the island, Banco de San Juan, and Banco Mercantil de Puerto Rico; the local branches of US Citibank and FirstBank; and foreign banks, such as Banco Santander, the the second largest bank in Puerto Rico, and Scotia Bank. The government owns and operates two specialized banks: the Government Development Bank (GDB) and the Economic Development Bank (EDB).

Banks offer a wide range of products and services such as checking and savings accounts, CDs, IRAs, loans, credit and debit cards, and electronic banking. Automatic teller machines are abundant, commonly referred to as ATHs. Banks are insured by the Federal Deposit Insurance Corporation and are subject to all federal controls applicable to banks in the mainland United States.

Climate change could affect the financial sector if the banks' investments are susceptible to climate changes, such as the manufacturing and tourism industries.

Box 4: Where will future coastal disasters occur?
By: Ernesto L. Díaz

Coastal and beach-front development in Puerto Rico has always faced storm damage. Risks in tropical islands have been traditionally accepted as inevitable. Before the 1960s coastal development was generally sparse. After the 1960s vacation or second homes became more popular. Beach houses were relatively inexpensive. An owner accepted loses induced by severe storms and exposition to floods and beach erosion. That owner would subsequently repair or re-build the vacation house affected by the storm.

Sea level rise continues to exacerbate the impacts associated to coastal hazards such as coastal storms, flooding, coastal erosion, and tsunamis. All of these hazards threaten lives, property, landscapes, habitats and, ultimately, coastal communities and economies.

Flooding may result from a coastal storm, tsunami, and river flooding or heavy precipitation events. Flood damages in Puerto Rico continue to escalate. Coastal erosion may result from storms, flooding, strong wave action, sea level rise, and human activities, such as inappropriate land use, alterations, and shore protection structures. Erosion undermines and often destroys homes, businesses, and public infrastructure and has short and long-term ecological, economic and social consequences.

Intensive development along 24% of Puerto Rico's coastal zone places people and property at risk to coastal hazards. Nature's ability to protect the human environment from severe hazards has been affected by the degradation of coral reefs and wetlands as well as the loss of sand dunes. As risks increase many beach front property owners resort to protect them with seawalls. Sea walls accelerate beach erosion and inhibit the beach's ability to absorb storm energy, thus exposing buildings to the full force of wind and waves. While adverse impacts can be reduced through proper planning of new coastal development, existing structures may need to be adapted, retro-fitted or protected. Managed or planned retreat may be required as shore erodes. In such cases buildings and other infrastructure are either demolished or relocated inland.

As sea level rises and storm surges and waves grow more intense traditional flood control will not be available to all potentially exposed coastal communities. Blocking, and diverting water is costly - economically and environmentally. How will decisions to protect, retrofit or letting structures flood be made? Which communities and structures will be protected? Which communities will continue to flood? The answers to these and other related questions will largely determine where next disasters will occur.

From a coastal engineering stand-point a coastal segment can be protected by blocking water. However, water will flow elsewhere. If a coastal property is protected by seawalls, the water does not simply dissipate. The wave energy is reflected at that particular segment, but erosion of the front, unprotected, and down-drift areas will accelerate. This is the case of vertical seawalls. Seawalls and other coastal defense structures can be designed to dissipate and reflect wave energy (i.e., curved, angled, stepped or mound). Offshore or submerged breakwaters are structures that parallel the shore and serve as wave absorbers. These forms of artificial reefs reduce wave energy in its lee side and typically create a tombolo behind the structure. In addition to protecting the coast they may enhance surf breaking for water sport activities and become habitat for marine life. However, offshore breakwaters are costly structures and relatively difficult to build. Again, costs and benefits of protecting a costal segment will be largely determined by the type of infrastructure exposed to the risk (i.e., airports, hotels, access roads).

Sea level rise in Puerto Rico will also have legal implications on coastal properties and the coastal public trust lands. The coastal public trust lands or maritime-terrestrial public domain are recognized as the space of the coasts of Puerto Rico subject to the ebb and flow of the tides, where tides are noticeable, and where the largest waves during ordinary storms are noticeable, where the tides are not noticeable. The maritime terrestrial zone also includes …land claimed by the sea, accessions and accretions, as well of those areas of the rivers that are navigable or up to the place where tides are
noticeable.

As rising seas "threaten" shoreline property, there will be increased pressure to armor shorelines to protect shoreline property interests. Those property owners that have the economic means will attempt to hold back the water with coastal structures, rocks, or any other barriers. Some properties will be inevitably inundated by the sea. Will the flooded property become public domain?

The gradual adoption of an Island-wide policy of retreat through the use of setbacks and rolling easements needs to be examined. These options among other could be combined to create a comprehensive policy response to sea level rise. Either approach, or a combination of both, among other could be incorporated into a Puerto Rico Coastal Statute.

As sea level rises and science becomes more certain policy makers and coastal managers will be faced with important decisions about protecting coastal properties, planned retreat, adapting, retrofitting, establishing adaptation setbacks and adaptation strategies in undeveloped areas, enabling wetlands inland migration and providing connectivity through biological corridors. These decisions have legal, social, economic, ecological, and esthetic implications. The Puerto Rico Climate Change Council provides a forum to proactively discuss these issues and effectively support current and prospective decision making.

ECONOMIC STUDIES

To the knowledge of the PRCCC, only one study has been conducted to determine the costs of climate change for Puerto Rico. The study was conducted by the Stockholm Environment Institute – U.S. Center and Tufts University. They found that the cost of global climate inaction for Puerto Rico is projected to reach $2.5 billion annually by 2050 and exceed $5 billion by 2100 (Bueno, Herzfeld, Stanton and Ackerman 2008). These costs represent nearly three percent and six percent, respectively, of Puerto Rico's GDP in 2004. These figures reflect impacts from only three categories, namely from decreased tourism, hurricane damages, and infrastructure damage due to sea-level rise. The projected damages are higher, in dollars, than for most of the other Caribbean islands assessed in the same report. However, they represent a smaller fraction of Puerto Rico's larger GDP (See table 2 below).

According to the study, most of the population lives in or near coastal zones, and most economic activity is located there as well, including most hotels, hospitals, and electric power plants; some power plants are less than 160 feet from the waterline and less than six feet about sea level. More than half of the population lives in the San Juan metropolitan area, which is very close to sea

(High-Impact minus Low-Impact Scenarios)

Puerto Rico	Cost of Inaction ($US Billions)			
	2025	**2050**	**2075**	**2100**
Storms	0.2	0.4	0.7	1.1
Tourism	0.2	0.5	0.7	1.0
Infrastructure	0.8	1.6	2.4	3.2
Total	**$1.2**	**$2.5**	**$3.8**	**$5.2**
% Current GDP	**1.4%**	**2.8%**	**4.4%**	**6.0%**

Sources: Authors' calculations. Amounts in 2007 dollars; percentages based on 2004 GDP.

Table 5. Puerto Rico—Low- and High-Impact Scenarios

Puerto Rico	Climate Change Scenarios: $US Billions			
LOW-IMPACT	**2025**	**2050**	**2075**	**2100**
Storms	0.3	0.3	0.3	0.3
Tourism	0.1	0.1	0.2	0.2
Infrastructure	0.1	0.3	0.4	0.6
Total	**$0.5**	**$0.7**	**$0.9**	**$1.1**
% Current GDP	**0.5%**	**0.8%**	**1.0%**	**1.3%**
HIGH-IMPACT	**2025**	**2050**	**2075**	**2100**
Storms	0.4	0.6	0.9	1.3
Tourism	0.3	0.6	0.9	1.2
Infrastructure	0.9	1.9	2.8	3.8
Total	**$1.7**	**$3.1**	**$4.7**	**$6.3**
% Current GDP	**1.9%**	**3.6%**	**5.4%**	**7.3%**

Sources: Authors' calculations. Amounts in 2007 dollars; percentages based on 2004 GDP.

Table 1: From Report Bueno, Herzfeld, Stanton and Ackerman 2008

level. A rise of three feet (almost a meter) in sea level could flood large parts of the city.

Puerto Rico was largely spared by major hurricanes during its decades of industrialization after WWII. In the last two decades, however, the island has faced damaging storms. For example, in 1989 Hurricane Hugo (a Category 3 storm) passed over the northeast corner of Puerto Rico and caused an estimated $1 billion in damages; Hurricane Georges (Category 2) crossed the island in 1998, leaving behind 12 dead and total damages amounting to $2.3 billion (Center for Integrative Environmental Research (CIER) 2007).

Economic studies are greatly needed for Puerto Rico in order to determine the real costs of the outcomes and consequences from climate change, both historically and projected into the future. By knowing the costs we can design adaptation strategies to reduce risks without breaking the bank. Because of Puerto Rico's dependence on the service industry and tourism, any future economic studies that are conducted should incorporate the losses from disrupted ecosystem services.

RESULTS FROM RISK ASSESSMENT WORKSHOPS

To validate preliminary results of the vulnerability assessment, the society and economy PRCCC Working Group 3 and various partner organizations and individuals conducted risk assessment workshops with coastal municipalities: *Workshops for the Evaluation of Current and Future Risks in the Coastal Zone*. Thirty of the forty-four coastal municipalities of Puerto Rico attended with representatives from planning offices, emergency managers, and public works officers (figure X). The PRCCC coordinators presented the preliminary findings and through a series of facilitated small group discussions the participants confirmed the main climate stressors impacting important sectors of their municipalities (e.g., infrastructure assets, economic development areas, and natural resources); further quantified the magnitude and likelihood of impacts occurring for the features assessed; and discussed the linkages between Island-wide concepts and municipal realities. Additionally, the last session of each workshop was devoted to the brainstorming of adaptation strategies by sectors identified as the most important by the workshop participants. Many of the consequences of certain climate stressors that the Working Group had identified as possibilities for the future, the municipal representatives identified as already occurring. This information was factored into the final results of this report, specifically into the development of a risk matrix.

RISK MATRIX FOR SOCIETAL ASSETS OF PUERTO RICO

To determine which societal assets of Puerto Rico were most at-risk due to climate change Working Group 3 developed a risk matrix. The preliminary information to form the risk matrix was collected at initial organizational meetings, where the working group members compiled a list of features and, as necessary, sub-features of their assigned subject. These features and sub-features were then aggregated into planning areas, and assessed during the risk assessment process. While the risk assessment described below utilized what appears to be a quantitative approach, the inherent limitations of the analytical tools delivered a more qualitative result. These results allowed us to develop a gross prioritization which will enable the PRCCC to focus their attention on the appropriate planning areas doing further analyses. Furthermore, these analyses were broad based; a more defined vulnerability analysis may be needed to define specific adaptive strategies though this is a good first step.

The risk assessment process was conducted through a mix of meetings, workshops and an online survey tool. Working group members completed the risk assessment survey and the information from the municipal risk assessment workshops were factored into the survey as well. Group discussion using a facilitated diagramming process (e.g., VCAPS), recorded by a facilitator, and the surveys were completed for each planning area and certain features. The risk matrix provided a space for each individual to evaluate the planning areas or features by the (1) likelihood impact by climate change by the year 2080 (Likelihood of Occurrence), (2) the severity of impact by 2080 (Magnitude of Impact), (3) the primary climate driver, and (4) the likely time horizon for impacts to occur and urgency for action during the temporal benchmarks of 2020, 2050, or 2080 (Time Urgency).

Risk for each feature was quantified by assigning positive or negative values of 1 (risk category= low) through 4 (risk category= high) to the Likelihood of Occurrence and 1 (risk category= low) through 3 (risk category= high) to the Magnitude of Impact components of the matrix. Likelihood and magnitude scores were multiplied to calculate values ranging from 1-12 for each of the blocks in the ranking table. Responses from each participant were thus transformed into numerical values that were averaged to produce risk scores. Each feature then was ranked by risk scores with time urgency listed.

The results of the risk assessment workshops with the coastal municipalities were included in the calculations. Table 2 is the result of this exercise.

Área de planificación	Planning Area	Average Likelihood	Average Magnitude	Average Risk Score	Climate Driver	Most often Given Time Answer
Características naturales que protejan la costa (Barreras naturales, como manglares, dunas, rocas o arrecifes de coral)	Natural characteristics that protect the coasts (natural barriers like mangroves, beach dune systems, rocks, and coral reefs)	3.88	3.00	**High** 11.63	No consistent answers (all 4)	2020; 2050
Estructuras de propiedad privada (viviendas unifamiliares y múltiples, edificios de oficinas, hoteles, edificios comerciales, estaciones de gasolina, y centros comerciales)	Private Structures (single and multi-family homes, office buildings, hotels, commercial buildings, gas stations, centers of commerce)	3.88	2.94	**High** 11.38	Sea Level; Storms	2020
Instalaciones y Edificios Públicos (gobierno, educación, salud, parques culturales, áreas recreativas, etc)	Public Buildings and Facilities (government, education, health, parks, recreation areas)	3.86	2.81	**High** 10.90	Sea Level; Storms	2020
Infraestructura de aguas usadas y escorrentía (Estructuras de recolección y transporte (canales, tuberías, bombas, alcantarillas, arroyos urbanos, quebradas); estructuras de captación (estanques, lagos urbanos, y sistemas de recolección de agua de lluvia), estructuras de control de calidad (por ejemplo, desarenadores); estructuras de almacenamiento, sistemas de desbordamiento de aguas residuales y pluviales, plantas de tratamiento y sistemas de descarga de aguas tratadas)	Wastewater and Stormwater Infrastructure (collection and transpor structure - canals, pipes, pumps, sewers, urban creeks and streams), catchment structures (ponds, lakes, urban systems and rainwater), quantity control structures, storage structures, overflow systems, wastewater treatment plants)	3.69	2.88	**High** 10.60	Precipitation; Temperature; Storms	2020

Transporte (puertos, carreteras, puentes)	Transportation (ports, roads, bridges)	3.75	2.75	**High** 10.31	Precipitation; Sea Level	2020
Infraestructura de Generación de Energía (Plantas de generación de energía; infraestructura de transmisión e infraestructura de distribución)	Energy Generation Infrastructure (energy generation plants, transmission and distribution infrastructure)	3.56	2.69	**High** 9.57	Sea Level; Storms	2020
Servicios de Agua (estructuras de almacenamiento, procesamiento y distribución de agua potable (tuberías principales de agua, etc.)	Water Services (structures for processing and distribution of drinking water - water mains, etc)	3.38	2.63	**Medium** 8.86	Precipitation; Temperature; Storms	2050; 2080
Suministro de Agua (recursos de agua superficial, aguas subterráneas y del subsuelo; acuíferos costeros; represas y energía hidroeléctrica)	Water Storage (surface water resources, groundwater resources; coastal aquifers; dams and hydropower)	3.38	2.56	**Medium** 8.65	Precipitation; Temperature	2080
Recursos de Agua para Irrigación y Drenaje	Water Resources for Irrigation and Drainage	3.38	2.53	**Medium** 8.55	Precipitation; Temperature	2050
Recursos Históricos y Culturales (lugares de interés histórico y significado cultural)	Historical and Cultural Resources (places of historical and cultural interest/ significance)	2.94	2.60	**Medium** 7.64	Sea Level; Storms	2050

Box 5: The psycho-spiritual value of nature conservation in the face of climate change

By: Dr. Antares Ramos

When we talk about the social importance for natural resources conservation, especially in the climate change scenario, we always discuss ecosystem services: coastal defense from natural events (e.g., the 100yr wave, hurricanes, tsunamis, etc.), fresh air, clean water, and even the enjoyment of future generations. But one vital aspect of nature conservation is the spiritual value of nature for human well-being, or mental well-being how colleagues from the health sector refer to it. I am not referring to spiritual from a religious point of view, even though for some it may transcend to that. It is that experience and connection that in some way gives meaning to one's existence in relation to the world we live in. It's "nature as an arena for the quality of life" (Hågvar 1999). It goes along the lines of 'going for a walk to clear the mind', to restore that mental balance and even become inspired. To facilitate the discussion presented here, I will use Schroeder's (1992) definition of spiritual:

"Spiritual"refers to the experience of being related to or in touch with an "other" that transcends one's individual sense of self and gives meaning to one's life at a deeper than intellectual level.

The spiritual value of nature has long been celebrated in art, literature, and music (Fairchild 1989, Schroeder 1992), but in the natural science sector it tends to be a taboo. Scientists trained in the natural sciences tend to avoid discussions on the spiritual phenomena. Easily understandable since it's a sector where we focus on facts and on tangible things. The human spiritual side is more of a social science topic, and it's only in recent years that social scientists have been integrated into natural resources conservation. If, however, we conceptualize the spiritual phenomena as being psychological in nature, it becomes a legitimate topic for scientific discussion (Maslow 1974, Schroeder 1992). I will therefore, refer to this needed human connection to nature and its importance in nature and ecosystem conservation as "psycho-spiritual values" (Callicott 1997).

Contact with nature has a high recreational value for mentally fatigued people (a phenomena we see on the rise, due to increase in constant sensorial stimulation in every life setting, even while driving), since it offers time of silence and distance from the sources of stress, which in turn allow for recharging energy and attention (Kaplan & Kaplan 1989). It allows us to clear the mind and reflect over the real values in life. One of Kaplan and Kaplan's (1989) conclusion was that "people feel more satisfied with their homes, with their jobs, and with their lives when they have sufficient access to nature in the urban environment".

New age medical doctors in Puerto Rico are using "green therapy", where part of the patient's treatment (e.g., cancer patients) involves some sort of contact with nature such as walks or even planned hike expeditions (depending on the condition of the patient). So even the medical sciences are beginning to recognize the importance of nature in the well-being of humans. It is important to understand that humans and nature cannot be separated, that the psycho-spiritual aspect is therefore an important component in nature conservation.

Especially in current times where climate change threatens many of the spaces we enjoy and also adds a stress to humankind, when we are losing homes due to coastal erosion and sea level rise, aquifers are in threat of becoming salinized, and changes in weather pattern are directly affecting our food production. Just as management efforts cannot ignore ecological interrelations among species and habitats, we need to recognize that ignoring the spiritual and psychological connections between humans and the natural world, and not allowing space for those experiences, can result in detrimental implications for society.

In Puerto Rico we are facing hard times as a society, with a decrease in education, a rise in criminality, and a tendency to focus in the material. We place mental health on a second plane and forget that the well-being of society depends on the well-being of its individuals who make the whole. In a time where our coastal areas are in peril due to sea-level rise, uncontrolled development, and coastal erosion due to harsher storms as a result to changes in long-term weather patterns, we need to further protect these areas that we as a society value. The Puerto Rican beach is an area where you will daily observe, no matter what time of day, people walking or jogging, playing with children, watching sunrises and sunsets and even meditating. A way to clear the mind and connect with nature and to satisfy our human need to understand and explore (Kaplan & Kaplan 1989). The loss of natural areas also implies that the country loses some of its identity (Kaplan & Kaplan 1989). Imagine Puerto Rico without its beaches? It even transcends to cultural values (Verschuuren 2006; Convention of Biological Diversity, 1992).

We do not need to go too far to see and understand the psycho-spiritual value of nature conservation. Many of us even seek it unconsciously. For others of us, it might even be a reason to continue defending nature. It is part of "ensuring that we leave a healthy and viable world for future generations" (Convention of Biological Diversity, 1992).

Literature cited

Convention of Biological Diversity (1992). 1760 UNTS 79; 31 ILM 818

Fairchild, J. (ed.) (1989). Trees: A celebration. New York: Weidenfeld and Nicolson. 128pp.

Hågvar, S. (1999). Nature as an arena for the quality of life: psycho-spiritual values-the next main focus in nature conservation?

Kaplan, R. & Kaplan, S.(1989). The experience of nature: A psychological perspective. Cambridge University Press.

Maslow, A.H. (1974). Religions, values, and peak experiences. New York: Viking Express. 123pp.

Schroeder, H.W. (1992). The spiritual aspect of nature: A perspective from Depth Psychology. In proceedings of Northeastern Recreation Research Symposium (p. 25-30), April 7-9, 1991, Saratoga Springs, NY.

Verschuuren, B. (2006). An overview of cultural and spiritual values in ecosystem management and conservation strategies. In proceedings of Endogenous Development and

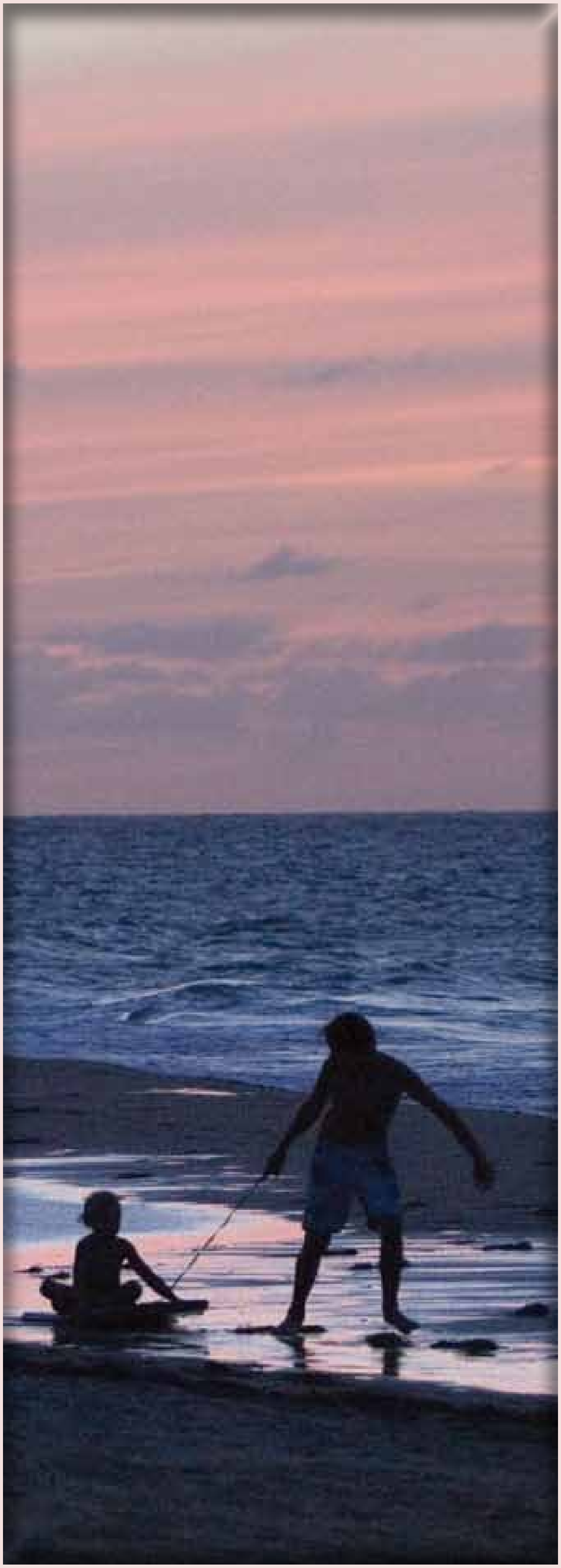
Bio-Cultural Diversity: The interplay of worldviews, globalization and locality (p. 299-325), 3-5 October 2006, Geneva, Switzerland.

CONCLUSION

Temperatures are increasing, precipitation patterns are changing, extreme events are occurring more frequently, oceans are more acidic, and sea level is rising. These climatic changes are projected to occur at much faster than natural rates. Some types of extreme weather and climate events have already increased in frequency and intensity and these changes are projected to continue.

Climate changes are already affecting some aspects of society, the economy and natural ecosystems of Puerto Rico and these effects are expected to increase. Not all of these changes will be gradual. When certain tipping points are crossed, impacts can increase dramatically. Past climate is no longer a reliable guide to the future. This affects planning for public and private infrastructure, tourism and industry, water resources, energy and all other social and economic systems.

In response to these changes, the Puerto Rico Climate Change Council (PRCCC) was convened in November 2010 to assess Puerto Rico's vulnerabilities and recommend strategies to respond to changes. The PRCCC is comprised of four working groups: (WG1) Geophysical and Chemical Scientific Knowledge; (WG2) Ecology and Biodiversity; (WG3) Society and Economy; and (WG4) Communicating Climate Change and Coastal Hazards. Based on the results of PRCCC's WG1, WG2 and WG3 as well as the results of coastal hazards risk assessment workshops conducted with thirty of the forty-four coastal municipalities, the PRCCC concludes that Puerto Rico's climate is changing and coastal communities of Puerto Rico, critical infrastructure, wildlife and ecosystems are all vulnerable to various impacts associated with changes in global, regional, and island weather and oceanographic conditions.



WORKS CITED

NYPCC 2010. Climate Change Adaptation in New York City: Building a Risk Management Response. New York City Panel on Climate Change 2010 Report: pp. 354.

APEGBC. 2010. Report of the Climate Change Task Force. Professional Engineers and Geoscientists of British Columbia. February 2010.

Adger, W. N. (1996). Approaches to vulnerability to climate change. Working paper no. GEC 96-05. London: Centre for Social and Economic Research on the Global Environment.

Adger, W. N. (1999). Social vulnerability to climate change and extremes in coastal Vietnam. World Development. 27(2), 249-269.

Adger, W. N., Brooks, N., Kelly, M., Bentham, G., Agnew, M. & Erisen, S (2004). New Indicators of Vulnerability and Adaptive Capacity. Technical Report Number 7. Norwich, UK: Tyndall Centre for Climate Change Research, University of East Anglia.

Adger, W. N. & Vincent, K. (2005). Uncertainty in adaptive capacity. Comptes Rendus Geoscience. 337(4), 399-410.

Allen Consulting (2005). Climate Change Risk and Vulnerability. Canberra: Australian Greenhouse Office, Department of Environment and Water Resources.

Bellamy, J., Smith, T., Taylor, B., McDonald, G., Walker, M., Jones, J. & Pero, L. (2005). Criteria and Methods for Monitoring and Evaluating Healthy Regional Planning Arrangements. Darwin: Tropical Savannas Management CRC.

Brooks, N., Adger, W. N. & Kelly, P. M. (2005). Determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Global Environmental Change. 15, 151-163.

Cain, J. (2001). Planning improvements in natural resources management. Guidelines for using Bayesian networks to support the planning and management of development programmes in the water sector and beyond. Centre for Ecology and Hydrology, Wallingford, UK.

CFMC (Caribbean Fishery Management Council). 2004. Final Environmental Impact Statement for the Generic Essential Fish Habitat Amendment to: Spiny Lobster, Queen Conch, Reef Fish, and Coral Fishery Management Plans for the U.S. Caribbean. Volume 1: Text, San Juan, PR.

CODREMAR (Corporation for the Development and Administration of Marine, Lacustrine, and Fluvial Resources of Puerto Rico). 1986. Survey of Associated and Independent Fishermen.

CSIRO & BOM (Bureau of Meteorology) (2007). Climate change in Australia: technical report 2007. CSIRO Marine and Atmospheric Research and the Bureau of Meteorology, Aspendale and Melbourne.

Department of Natural and Environmental Resources (DNER). 2000. Activity and Harvest Patterns in Puerto Rico Marine Recreational Fisheries. Annual Report, Project F-42.1, Puerto Rico Marine Recreational Fishery Statistic Program, San Juan, PR.

Dybas, C.L. 2006. On a collision course: Ocean plankton and climate change. BioScience 56(8): 642-646.

Folk, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C. S., Walker, B., Bengtsson, J., Berkes, K., Colding, J., Danell, K., Falkenmark, M., Gordon, L., Kasperson, R., Kautsky, N., Kinzig, A., Levin, S., Maler, K., Moberg, F., Ohlsson, L., Olsson, P., Ostrom, E., Reid, W., Rockstrom, J., Savenije, H., & Svedin, U. (2002). Resilience and Development: Building Adaptive Capacity in a World of Transformations. ICSU Series on Science for Sustainable Development: Resilience and Sustainable Development, No. 3. Stockholm.

Füssel, H.-M. (2007). Adaptation planning for climate change: concepts, assessment approaches, and key lessons. Sustainability Science. 2, 265-275.

Griffith, D.C., J.C. Johnson, R. Chaparro Serano, M. Valdes Pizzini, and J.D. Murray. 1988. Developing Marine Recreational Fishing in Puerto Rico and the U.S. Virgin Islands. Final Report for NOAA/NMFS Grant NA86WC-H-06108.

Inman, M. 2005. Fish moved by warming waters. Science 308: 937.

Intergovernmental Panel on Climate Change (2001). In: McCarthy, J., Caziani, O., Leary, N., Dokken, D. & White, K. (eds.) Climate change 2001: Impacts, adaptation, and vulnerability. Cambridge: Cambridge University Press.

Intergovernmental Panel on Climate Change. (2007). Climate change 2007: the physical science basis. Summary for policymakers. Contribution of working group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Geneva: IPCC Secretariat, 21 pp.

Jensen, F. V. (1996). An introduction to Bayesian networks. Springer-Verlag: New York.

Kintisch, E. 2006. As the seas warm. Science 313: 776-779.

Kjaerulff, U. B. & Madsen, A. L. (2008). Bayesian Networks and Influence Diagrams: A Guide to Construction and Analysis. Springer: New York.

Lebel, L., Anderies, J. M., Campbell, B., Folke, C., Hatfield-Dodds, S., Hughes. T. P. & Wilson, J. (2006). Governance and the capacity to manage resilience in regional social-ecological systems. Ecology and Society.11(1): 19. [online] URL: http://www.ecologyandsociety.org/vol11/iss1/art19/

Naess, L. O., Bang, G., Eriksen, S., & Vevatne, J. (2005). Institutional adaptation to climate change: Flood responses at the municipal level in Norway. Global Environmental Change. 15(2), 125-138.

Matos-Caraballo, D. 2004. Comprehensive Census of the Marine Fishery of Puerto Rico, 2002. Final Report submitted to National Marine Fisheries Service, Job 3, Department of Natural and Environmental Resources, San Juan, PR.

Office of Urban Management. (2005). South East Queensland Regional Plan 2005-2026. Brisbane: Queensland Department of Local Government, Planning, Sport and Recreation.

Portner, H.O., and R. Knust. 2007. Climate change affects marine fishes through the oxygen limitation of thermal tolerance. Science 315: 95-97.

Preston, B. L. & Jones, R. N. (2006). Climate Change Impacts on Australia and the Benefits of Early Action to Reduce Global Greenhouse Gas Emissions. A consultancy report prepared for the Australian Climate Change Business Roundtable.

Preston, B. L., Smith, T., Brooke, C., Gorddard, R., Measham, T., Withycombe, G., McInnes, K., Abbs, D., Beveridge, B. & Morrison, C. (2008). Mapping Climate Change Vulnerability in the Sydney Coastal Councils Group. Canberra: Sydney Coastal Councils Group, the Commonwealth Department of Climate Change, CSIRO Climate Adaptation Flagship, Canberra.

Queensland Department of Infrastructure and Planning (2008). Sunshine Coast population and housing fact sheet. Brisbane: Queensland Department of Infrastructure and Planning, February 2008.

Richardson, A.J., and D.S. Schoeman. 2004. Climate impact on plankton ecosystems in the Northeast Atlantic. Science 305: 1609-1612

Sen, A. (1981). Poverty and Famines. Oxford: Clarendon Press.

Smith, T. F. (in press). Beyond knowledge: A neo-research approach to enhance climate change adaptation. In J. Martin (ed.) Climate Change Responses across Regional Australia: Social Learning and Adaptation. Victoria: VURRN Press.

Smith, T. F., Brooke, C., Measham, T. G., Preston, B., Gorddard, R., Withycombe, G., Beveridge, B. & Morrison, C. (2008). Case Studies of Adaptive Capacity: Systems Approach to Regional Climate Change Adaptation Strategies. Canberra: Sydney Coastal Councils Group, the Commonwealth Department of Climate Change, CSIRO Climate Adaptation Flagship, Canberra.

Smith, T. F. & Smith, D. C. (2006). Institutionalising Adaptive Learning For Coastal Management. In Lazarow, N., Souter, R., Fearon, R. and Dovers, S. (eds.) Coastal Management in Australia: Key institutional and governance issues for coastal natural resource management and planning. Brisbane: CRC for Coastal Zone, Estuary and Waterway Management. pp. 115-120.

Stokestad, E. 2004. Changes in planktonic food web hint at major disruptions in Atlantic. Science 305: 1548-1549.

Tompkins, E. L. & Adger. W. N. (2004). Does adaptive management of natural resources enhance resilience to climate change? Ecology and Society. 9(2): 10. [online] URL:http://www.ecologyandsociety.org/vol9/iss2/art10/

Woodruff, D., Hales, S., Butler, C. & McMichael, A. (2005). Climate Change Health Impacts in Australia: Effects of Dramatic CO2 Emissions Reductions. Australian Conservation Foundation and the Australian Medical Association.

Yohe, G. & Tol, R. S. J. (2002). Indicators for social and economic coping capacity: Moving towards a working definition of adaptive capacity. Global Environmental Change, 12 (1), 25-40.

Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, Eds., 2008: Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 pp.

Ecological Society of America (1997). Climate Change, Hurricanes and Tropical Storms and Rising Sea Level Rise in Coastal Wetlands. Ecological Applications, 7(3), 1997, pp. 770–801

IPCC (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability . Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, Martin L., Canziani, Osvaldo F., Palutikof, Jean P., van der Linden, Paul J., and Hanson, Clair E. (eds.)].

Cambridge University Press, Cambridge, United Kingdom, 1000 pp.

Millán Rodríguez, Yamilet . 2011. Costosa solucion para la calidad del agua. El Vocero 26 December 2011.

National Wildlife Federation. (2011) Global Warming is Affecting Weather. (http://www.nwf.org/Global-Warming/What-is-Global-Warming/Global-Warming-is-Causing-Extreme-Weather/Hurricanes.aspx)

UNWTO (World Tourism Organization), UNEP (United Nations Environment Programme), and WMO (World Meteorological Organization). 2008. *Climate Change and Tourism: Responding to Global Challenges*. Madrid and Paris.

Peter H. Gleick, Briane Adams. (2000) Water: The Potential Consequences of Climate Variability and Change for the Water Resources of the United States. Pacific Institute for Studies in Development, Environment, and Security and U.S. Geological Survey.

Timms, W, Andersen, M.S. and Carley, J (2008). Fresh-saline groundwater boundaries below coastlines - potential impacts of climate change. Coast To Coast Crossing Boundaries Conference, 18-22 August, 2008, Darwin.

UNESCO, The United Nations World Water Development Report 2 (2006) Section 2: Changing Natural Systems, Chapter 4 (UNESCO & WMO, with IAEA), Part 3. Human Impacts, p.136

USGS.(1989) Water Resources in Puerto Rico and the US Virgin Islands 8(5/6):1-8. US Department of the Interior Geological Survey. San Juan, PR.

Rutty, M., and D. Scott. 2010. Will the Mediterranean become "too hot" for tourism? A reassessment. *Journal of Tourism Hospitality and Planning Development* 7 (3): 267–81.

Bueno, Ramón, Herzfeld, Cornelia, Stanton, Elizabeth A. and Ackerman, Frank (2008) 'The Caribbean and Climate Change: The Costs of Inaction', in: Stockholm Environment Institute and Tufts University): 37.

Center for Integrative Environmental Research (CIER) (2007) 'The US Economic Impacts of Climate Change and the Costs of Inaction', in (College Park, MD: University of Maryland).

Edward Means III, Maryline Laugier, Jennifer Daw, Laurna Kaatz, Marc Waage, Denver Water (2010) 'Decision Support Planning Methods: Incorporating Climate Change Uncertainties into Water Planning', in Water Utility Climate Alliance (WUCA) (ed) (Irvine, CA: Malcolm Pirnie, Inc.): 102.

Engineers, Canadian Council of Professional (2008) 'Adapting to Climate Change: Canad's First National Engineering Vulnerability Assessment of Public Infrastructure', in: 71.

FEMA (2012) 'Seven months later, disaster aid surpasses $83.9 million', in, *Press Release* (Online: www.fema.gov: Federal Emergency Management Agency).

References – Working Group 3: Society and Economy

(APEGBC) Association of Professional Engineers and Geoscientists of British Columbia. 2010. Report of the Climate Change Task Force. Professional Engineers and Geoscientists of British Columbia. February 2010.

Adger, W. N. (1996). Approaches to vulnerability to climate change. Working paper no. GEC 96-05. London: Centre for Social and Economic Research on the Global Environment.

Adger, W. N. (1999). Social vulnerability to climate change and extremes in coastal Vietnam. World Development. 27(2), 249-269.

Adger, W. N., Brooks, N., Kelly, M., Bentham, G., Agnew, M. & Erisen, S (2004). New Indicators of Vulnerability and Adaptive Capacity. Technical Report Number 7. Norwich, UK: Tyndall Centre for Climate Change Research, University of East Anglia.

Adger, W. N. & Vincent, K. (2005). Uncertainty in adaptive capacity. Comptes Rendus Geoscience. 337(4), 399-410.

Allen Consulting (2005). Climate Change Risk and Vulnerability. Canberra: Australian Greenhouse Office, Department of Environment and Water Resources.

Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, Eds., 2008: Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 pp.

Bellamy, J., Smith, T., Taylor, B., McDonald, G., Walker, M., Jones, J. & Pero, L. (2005). Criteria and Methods for Monitoring and Evaluating Healthy Regional Planning Arrangements. Darwin: Tropical Savannas Management CRC.

Brooks, N., Adger, W. N. & Kelly, P. M. (2005). Determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Global Environmental Change. 15, 151-163.

Bueno, R., C. Herzfeld, E.A. Stanton, F. Ackerman. (2008). The Caribbean and Climate Change: The Costs of Inaction. Stockholm Environment Institute and Tufts University: 37.

Cain, J. (2001). Planning improvements in natural resources management. Guidelines for using Bayesian networks to support the planning and management of development programmes in the water sector and beyond. Centre for Ecology and Hydrology, Wallingford, UK.

(CIER) Center for Integrative Environmental Research. (2007). 'The US Economic Impacts of Climate Change and the Costs of Inaction', in (College Park, MD: University of Maryland).

(CFMC) Caribbean Fishery Management Council. (2004). Final Environmental Impact Statement for the Generic Essential Fish Habitat Amendment to: Spiny Lobster, Queen Conch, Reef Fish, and Coral Fishery Management Plans for the U.S. Caribbean. Volume 1: Text, San Juan, PR.

(CODREMAR) Corporation for the Development and Administration of Marine, Lacustrine, and Fluvial Resources of Puerto Rico. (1986). Survey of Associated and Independent Fishermen.

CSIRO & BOM (Bureau of Meteorology). (2007). Climate change in Australia: technical report 2007. CSIRO Marine and Atmospheric Research and the Bureau of Meteorology, Aspendale and Melbourne.

(DNER) Department of Natural and Environmental Resources. (2000). Activity and Harvest Patterns in Puerto Rico Marine Recreational Fisheries. Annual Report, Project F-42.1, Puerto Rico Marine Recreational Fishery Statistic Program, San Juan, PR.

(DNER Plan de Agua) Puerto Rico Department of Environmental and Natural Resources. (2008). Plan Integral de Recursos de Agua de Puerto Rico.

Dybas, C.L. (2006). On a collision course: Ocean plankton and climate change. BioScience 56(8): 642-646.

Ecological Society of America (1997). Climate Change, Hurricanes and Tropical Storms and Rising Sea Level Rise in Coastal Wetlands. Ecological Applications, 7(3), 1997, pp. 770–801

Edward Means III, Maryline Laugier, Jennifer Daw, Laurna Kaatz, Marc Waage, Denver Water (2010) 'Decision Support Planning Methods: Incorporating Climate Change Uncertainties into Water Planning', in Water Utility Climate Alliance (WUCA) (ed) (Irvine, CA: Malcolm Pirnie, Inc.): 102.

Engineers, Canadian Council of Professional (2008). Adapting to Climate Change: Canad's First National Engineering Vulnerability Assessment of Public Infrastructure', in: 71.

(EPA) Environmental Protection Agency. (2008). Online resources.

(EPA) Environmental Protection Agency. (2012). Solid Waste in Puerto Rico. Online resource: http://www.epa.gov/region2/cepd/solidwaste_in_puerto_rico.html

FEMA (2012) 'Seven months later, disaster aid surpasses $83.9 million', in, *Press Release* (Online: www.fema.gov: Federal Emergency Management Agency).

Folk, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C. S., Walker, B., Bengtsson, J., Berkes, K., Colding, J., Danell, K., Falkenmark, M., Gordon, L., Kasperson, R., Kautsky, N., Kinzig, A., Levin, S., Maler, K., Moberg, F., Ohlsson, L., Olsson, P., Ostrom, E., Reid, W., Rockstrom, J., Savenije, H., & Svedin, U. (2002). Resilience and Development: Building Adaptive Capacity in a World of Transformations. ICSU Series on Science for Sustainable Development: Resilience and Sustainable Development, No. 3. Stockholm.

Füssel, H.-M. (2007). Adaptation planning for climate change: concepts, assessment approaches, and key lessons. Sustainability Science. 2, 265-275.

Gleick, P.H. and B. Adams. (2000). Water: The Potential Consequences of Climate Variability and Change for the Water Resources of the United States. Pacific Institute for Studies in Development, Environment, and Security and U.S. Geological Survey.

Gregory Morris Engineering PSC. (2009). Water Accountability Pilot Project Final Report. Puerto Rico Aqueduct and Sewer Authority.

Griffith, D.C., J.C. Johnson, R. Chaparro Serano, M. Valdes Pizzini, and J.D. Murray. (1988). Developing Marine Recreational Fishing in Puerto Rico and the U.S. Virgin Islands. Final Report for NOAA/NMFS Grant NA86WC-H-06108.

Inman, M. (2005). Fish moved by warming waters. Science 308: 937.

Insurance Information Institute. (2012). Online Access: http://www.iii.org/

Intergovernmental Panel on Climate Change. (2001). In: McCarthy, J., Caziani, O., Leary, N., Dokken, D. & White, K. (eds.) Climate change 2001: Impacts, adaptation, and vulnerability. Cambridge: Cambridge University Press.

Intergovernmental Panel on Climate Change. (2007). Climate change 2007: the physical science basis. Summary for policymakers. Contribution of working group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Geneva: IPCC Secretariat, 21 pp.

IPCC (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, Martin L., Canziani, Osvaldo F., Palutikof, Jean P., van der Linden, Paul J., and Hanson, Clair E. (eds.)]. Cambridge University Press, Cambridge, United Kingdom, 1000 pp.

Jensen, F. V. (1996). An introduction to Bayesian networks. Springer-Verlag: New York.
Kintisch, E. 2006. As the seas warm. Science 313: 776-779.

Kjaerulff, U. B. & Madsen, A. L. (2008). Bayesian Networks and Influence Diagrams: A Guide to Construction and Analysis. Springer: New York.

Kundzewicz, Z. W., Mata, L. J., Arnell, N., Döll, P., Kabat, P., Jiménez, B., Miller, K., Oki, T., Şen, Z. & Shiklomanov, I. (2007) Freshwater resources and their management. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (ed. by M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden & C. E. Hanson), 173–210. Cambridge University Press, UK. http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter3.pdf

Lebel, L., Anderies, J. M., Campbell, B., Folke, C., Hatfield-Dodds, S., Hughes. T. P. & Wilson, J. (2006). Governance and the capacity to manage resilience in regional social-ecological systems. Ecology and Society.11(1): 19. [online] URL: http://www.ecologyandsociety.org/vol11/iss1/art19/

Matos-Caraballo, D. (2004). Comprehensive Census of the Marine Fishery of Puerto Rico, 2002. Final Report submitted to National Marine Fisheries Service, Job 3, Department of Natural and Environmental Resources, San Juan, PR.

Millán Rodríguez, Yamilet. (2011). Costosa solucion para la calidad del agua. El Vocero 26 December 2011.

Naess, L. O., Bang, G., Eriksen, S., & Vevatne, J. (2005). Institutional adaptation to climate change: Flood responses at the municipal level in Norway. Global Environmental Change. 15(2), 125-138.

National Wildlife Federation. (2011) Global Warming is Affecting Weather. (http://www.nwf.org/Global-Warming/What-is-Global-Warming/Global-Warming-is-Causing-Extreme-Weather/Hurricanes.aspx)

(NYPCC) New York City Panel on Climate Change. 2010. Climate Change Adaptation in New York City: Building a Risk Management Response. New York City Panel on Climate Change 2010 Report: pp. 354.

Office of Urban Management. (2005). South East Queensland Regional Plan 2005-2026. Brisbane: Queensland Department of Local Government, Planning, Sport and Recreation.

(PIRA) Plan Integral de Recursos de Agua (2008). Plan Integral de Recursos de Agua de Puerto Rico. http://www.recursosaguapuertorico.com/Plan-Integral-Aguas-.html

Portner, H.O., and R. Knust. 2007. Climate change affects marine fishes through the oxygen limitation of thermal tolerance. Science 315: 95-97.

(PRASA) Puerto Rico Aqueduct and Sewer Authority (2010). Study of Desirability and Convenience for the Implementation for Advanced Technologies for the Reduction of Non-Revenue Water. Puerto Rico Public-Private Partnerships Authority.

Preston, B. L. & Jones, R. N. (2006). Climate Change Impacts on Australia and the Benefits of Early Action to Reduce Global Greenhouse Gas Emissions. A consultancy report prepared for the Australian Climate Change Business Roundtable.

Preston, B. L., Smith, T., Brooke, C., Gorddard, R., Measham, T., Withycombe, G., McInnes, K., Abbs, D., Beveridge, B. & Morrison, C. (2008). Mapping Climate Change Vulnerability in the Sydney Coastal Councils Group. Canberra: Sydney Coastal Councils Group, the Commonwealth Department of Climate Change, CSIRO Climate Adaptation Flagship, Canberra.

Queensland Department of Infrastructure and Planning (2008). Sunshine Coast population and housing fact sheet. Brisbane: Queensland Department of Infrastructure and Planning, February 2008.

Richardson, A.J., and D.S. Schoeman. (2004). Climate impact on plankton ecosystems in the Northeast Atlantic. Science 305: 1609-1612.

Rutty, M., and D. Scott. 2010. Will the Mediterranean become "too hot" for tourism? A reassessment. *Journal of Tourism Hospitality and Planning Development* 7 (3): 267–81.

Sen, A. (1981). Poverty and Famines. Oxford: Clarendon Press.

Smith, T. F. (in press). Beyond knowledge: A neo-research approach to enhance climate change adaptation. In J. Martin (ed.) Climate Change Responses across Regional Australia: Social Learning and Adaptation. Victoria: VURRN Press.

Smith, T. F., Brooke, C., Measham, T. G., Preston, B., Gorddard, R., Withycombe, G., Beveridge, B. & Morrison, C. (2008). Case Studies of Adaptive Capacity: Systems Approach to Regional Climate Change Adaptation Strategies. Canberra: Sydney Coastal Councils Group, the Commonwealth Department of Climate Change, CSIRO Climate Adaptation Flagship, Canberra.

Smith, T. F. & Smith, D. C. (2006). Institutionalising Adaptive Learning For Coastal Management. In Lazarow, N., Souter, R., Fearon, R. and Dovers, S. (eds.) Coastal Management in Australia: Key institutional and governance issues for coastal natural resource management and planning. Brisbane: CRC for Coastal Zone, Estuary and Waterway Management. pp. 115-120.

Stokestad, E. (2004). Changes in planktonic food web hint at major disruptions in Atlantic. Science 305: 1548-1549.

Timms, W, Andersen, M.S. and Carley, J (2008). Fresh-saline groundwater boundaries below coastlines - potential impacts of climate change. Coast To Coast Crossing Boundaries Conference, 18-22 August, 2008, Darwin.

(UNEP) United Nations Environment Programme Global Environment Monitoring System (GEMS)/Water Programme. (2008) Water Quality for Ecosystem and Human Health, 2nd Edition.

UNESCO, United Nations World Water Development Report 2 (2006) Section 2: Changing Natural Systems, Chapter 4 (UNESCO & WMO, with IAEA), Part 3. Human Impacts, p.136

(UNWTO) United Nations World Tourism Organization, UNEP (United Nations Environment Programme), and (WMO) World Meteorological Organization. (2008). *Climate Change and Tourism: Responding to Global Challenges*. Madrid and Paris.

USGS. (1989) Water Resources in Puerto Rico and the US Virgin Islands 8(5/6):1-8. US Department of the Interior Geological Survey. San Juan, PR.

Tompkins, E. L. & Adger. W. N. (2004). Does adaptive management of natural resources enhance resilience to climate change? Ecology and Society. 9(2): 10. [online] URL:http://www.ecologyandsociety.org/vol9/iss2/art10/

Woodruff, D., Hales, S., Butler, C. & McMichael, A. (2005). Climate Change Health Impacts in Australia: Effects of Dramatic CO2 Emissions Reductions. Australian Conservation Foundation and the Australian Medical Association.

Yohe, G. & Tol, R. S. J. (2002). Indicators for social and economic coping capacity: Moving towards a working definition of adaptive capacity. Global Environmental Change, 12 (1), 25-40.