Report: Assessing the San Juan Bay Estuary Program's Vulnerabilities to Climate Change

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CLIMATE READY ESTUARIES
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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Programa del Estuario de la Bahía de San Juan

Assessing the San Juan Bay Estuary Program's Vulnerabilities to Climate Change

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Introduction

The San Juan Bay Estuary is a coastal area where freshwater flowing from rivers and streams mixes with salt water in the Estuary's bays, lagoons, and channels, and ultimately, the ocean. The Estuary covers a 242 square kilometer area, and includes nine major water bodies, namely: San Juan Bay, Condado Lagoon, San Jose Lagoon, Los Corozos Lagoon (connects directly to San Jose Lagoon), La Torrilla or Torrecilla Lagoon, the Martin Pena and San Antonia(o) Channels, the Suarez Canal, and Piñones Lagoon. The San Juan Bay Estuary provides valuable resources to the region and the island of Puerto Rico.

The Estuary supports a busy port, and is home to attractive beaches, parks, natural areas, and recreational fishing resources. The Estuary is also uniquely tropical, having features including coral communities, seagrass beds, and mangrove forests. However, the needs of an increasing population and a growing economy have resulted in degradation and destruction of many components of the San Juan Bay Estuary. As a result of its uniqueness and the threats to its health, the Governor of Puerto Rico nominated the San Juan Bay Estuary to the United States Environmental Protection Agency's (EPA) National Estuary Program (NEP). The Estuary was recognized as an Estuary of National Significance and added to NEP by EPA in 1992. A Comprehensive Conservation and Management Plan (CCMP) that focuses on problems and potential actions to improve the quality of the Estuary was signed by the Governor and EPA Administrator in 1993, the CCMP was updated in 2000 and most recently in 2013.

The Comprehensive Conservation and Management Plan (CCMP) for the San Juan Bay Estuary (SJBE) have identified several goals and approaches to achieve better environmental health within this estuary. Among the proposed activities, cleanup and dredging of the Martín Peña Channel (CCMP Action WS-5), filling of the deep holes in San Jose and Condado Lagoons caused by dredging (CCMP Actions HW-2 and WS-6), and minimization of untreated sewage inputs from point and non-point sources (CCMP Actions WS-1, WS-3, and WS-4) emerge as some of the priorities of the CCMP. It is expected that the combined effects of these measures will enhance the water quality of the SJBE.

As highlighted in the 2013 update, the threats to the San Juan Bay Estuary and the SJBE Program's objectives might be exacerbated due to the new challenge of climate change. Globally, the past three decades have been the warmest since temperatures started being measured systematically in 1850 and reliable records maintained, reflecting an average increase of 1° C (5° F) for the period between 1900 and 2010. According to the Intergovernmental Panel on Climate Change (IPCC) global temperatures have increased an average of 0.74° C (1.35 ° F) since 1906 and are expected to rise another 1.4° C (1.8 - 7.2 ° F) at the end of the 21st century, depending on the amount of greenhouse gas emissions released into the atmosphere by energy and land use practices in the future. Temperature increases and changes in carbon dioxide concentrations in the atmosphere are causing rainfall patterns to change, the oceans are becoming more acidic, sea levels are rising and extreme events are occurring more frequently (PRCCC 2013).

Climate Ready Estuaries is a program that works with the National Estuary Programs (NEP) assessing how the nation's estuaries will respond to these climate changes and works to develop and implement adaptation strategies, engage and educate stakeholders. The Climate Ready Estuaries (CRE) Program provides information on climate change impacts in different estuaries in the region, provides the

platform for access to tools and resources to monitor changes, information to help people with decision-making power to develop adaptation strategies for estuaries and coastal communities.

The NEP was established under Section 320 of the 1987 Clean Water Act (CWA) Amendments as a U.S. Environmental Protection Agency (EPA) place-based program to protect and restore the water quality and ecological integrity of estuaries of national significance. 2012 was the 25th anniversary of the National Estuary Program (NEP) and marked the fifth year that EPA's Climate Ready Estuaries has supported climate change adaptation activities in NEP study areas.

CRE is currently in the process of developing a new tool, a CRE Workbook, titled: Climate Change Risk Management: Preparing Vulnerability Assessments and Action Plans for Climate Adaptation. The CRE Workbook helps meet the need for guidance on conducting vulnerability assessments, provides decision-support tools, helps to address climate change adaptation, and builds the capacity of local environmental managers. Creating the CRE Workbook helps EPA to fulfill the commitments that the agency made to assist local organizations to effectively plan for climate change impacts. The CRE Guidebook is designed as a step by step approach that will guide environmental managers through the development of a broad assessment of climate change risks in their own places.

The objective of this project was to implement the draft protocol workbook for completing the San Juan Bay Estuary Program's climate change vulnerability assessment as a pilot project for the EPA Office of Water. Throughout the process of working through the CRE guidance, recommendations were sent to the EPA Office of Water through email and phone correspondences as well as through a workshop with other NEP managers in Washington, DC in February 2013.

Climate change will bring more challenges to places and ecosystems that are already under environmental pressures. The expected climate changes will worsen existing problems and bring new problems too. The process described in the draft CRE Workbook leads you to take a broad look at how climate change will affect your environmental system and your organization. The creation of a high level, risk – based vulnerability assessment will help you develop an action plan that considers cooperative solutions that your stakeholders and partners can help implement.

Managers who realize that climate change will affect the ability of their organization to meet its goals will be incorporating climate change risks into their planning. The audience for this CRE Guidebook is environmental professionals at organizations that look after environmental resources, especially organizations with a coastal or watershed focus. The CRE Workbook presents an approach to climate change adaptation planning based on EPA's experience with watershed management, the National Estuary Program, and the Climate Ready Estuaries program.

Planning for climate change impacts is a two-part process. In the first part—vulnerability assessment—managers identify and assess the climate change risks that may be a threat to their organizational goals. Part I is what the San Juan Bay Estuary Program piloted. The second part—developing an action plan—uses the vulnerability assessment to set priorities and develop responses. Ideally, adaptation responses will eliminate or reduce risks from climate change.

This Project was meant to start the SJBEP on the path to becoming a Climate Ready Estuary. The long-term objective is to develop and implement climate change adaptation strategies. While not within the scope of this Project the recommendations found at the end of this report offer a few related to adaptation strategies based off the findings of this vulnerability assessment (Phase I of the CRE Workbook). Conduct Phase II of the CRE Workbook would be one way of achieving a more

comprehensive review of adaptation options for the SJBEP.

The San Juan Bay Estuary Program (SJBEP) pays special attention to climate change impacts such as erosion, invasive species, and floods among other impacts that affect estuarine communities. The SJBEP has coordinated with scientists to inform citizens about the impacts of climate change. It is also important to know what the perception of communities to these changes is why it's vital conducting a vulnerability analysis to assess these risks before possible adaptation strategies. The SJBEP has a few initiatives to inform the community about climate change for example educational display about climate change, scientific investigations about sea level rise, water quality monitoring program and climate change citizen guide. In 2008 this NEP conducted a face-to-face poll on this topic with over 800 participants, and launched the first climate-change public service campaign, for which several ads were placed without cost through the Island's newspapers and TV stations. In 2011, the SJBEP joined the Sierra Club in its "Cool Cities" campaign, and printed a Spanish manual geared towards reducing the carbon footprint of municipalities. Most recently, the SJBEP revised its Comprehensive Conservation Management Plan to include several new actions on climate change and submitted a proposal to join the NEP/USEPA Climate Ready Estuary[1] (CRE) initiative. The proposal was approved and the San Juan Bay Estuary chosen as the site to field test steps 1 through 5 of the new CRE workbook.

[1] Resources of CRE:
http://water.epa.gov/type/oceb/nep/index.cfm
http://water.epa.gov/type/oceb/cre/index.cfm
http://water.epa.gov/type/oceb/cre/upload/CRE_2012Report_122612a.pdf

Methods

The methods used to complete this Pilot Project were to run through the CRE Workbook Steps 1-5 (described in next section), conduct workshops and meeting with stakeholders of the SJBEP, and specifically consult and inform environmental justice communities of the estuary through workshops. Here's an outline of the steps and who took the lead for each.

- Step 1: Communication and Consultation (SJBEP Staff and KJacobs)
    - September 2012 Technical Stakeholder Workshop
    - Informal meetings about process
- Step 2: Establishing the context for the vulnerability assessment (KJacobs)
- Step 3: Risk Identification
    - Conduct Workshops (A.Isabel Pares with assistance of KJacobs)
    - Compile table of identified risks, organized by SJBEP's organizational goals and objectives (KJacobs)
    - Review of risk identification table with SJBEP staff, CRE staff, and other NEP Programs (KJacobs)
    - Provide recommendations to CRE
- Step 4: Risk Analysis (KJacobs)
    - Expand CREWorkbook Risk Analysis spreadsheet for SJBEP purposes
    - Assess consequence, likelihood, spatial extent, and time scale for each identified risk
    - Provide recommendations to CRE
    - Review of risk analyses with researchers from University of Puerto Rico, SJBEP staff and STAC, and Puerto Rico Climate Change Council members
- Risk Evaluation/Comparing Risks (KJacobs, SJBEP Staff, A. Isabel Pares)
    - Create consequence/probability matrix for all organizational goals and individual matrices for each organizational goal
    - Review of vulnerability assessment with researchers from University of Puerto Rico, SJBEP staff and STAC, stakeholders, environmental justice communities, and Puerto Rico Climate Change Council members

Guidebook steps

Part 1: Vulnerability Assessments

Step 1: Communication and Consultation
Informing Key people about the vulnerability assessments and asking for input

Step 2: Establishing the context for the vulnerability assessment
Identifying organizational goals and objectives that are susceptible to climate change

Step 3: Risk Identification
Brainstorming about how climate stressors will impact with your goals and objectives

Step 4: Risk analysis
Developing an initial characterization of consequence and likelihood for each risk

Step 5: Risk Evaluation / Comparing Risks
Using a consequence/ probability matrix to reach consensus about each risk

Part2: Action Plan and Implementation

Step 6: Establishing the context for the action plan
Identifying the criteria you will use to make adaptation decisions

Step 7: Risk evaluation/ Deciding on a course
Deciding at a high level whether you will mitigate, transfer, avoid or accept each risk.

Step 8a: Develop a short list of adaptation actions
Scanning potential mitigating actions to identify ones of interest for further investigation

Step 8b: Asses effectiveness of adaptation action
Answering questions about the mitigating actions identified in step 8a

Step 9: Prepare and implement action plan
Creating a plan track mitigating actions and which risks they address

Step 10: Monitoring and review
Keeping track of the effectiveness of your adaptation actions

Workshops

An invitational workshop, *Climate Change Vulnerability Assessment-San Juan Bay Estuary,* was conducted with 26 invited specialists from federal and local agencies, international and local non-governmental organizations, university programs, a neighboring National Estuarine Research Reserve, and the private sector in September 2012. The workshop described the CRE program, the draft guidebook, and then through a hands-on workshop participants helped the SJBEP begin Step 3 – the Risk Identification Process. The participants also provided recommendations to the SJBEP staff for the continuation of the vulnerability assessment.

Three workshops with communities surrounding the estuary were conducted to determine community values, concerns, observations and insights of climate change-related issues. Two of the workshops were specific to environmental justice communities living around the estuary. The workshop programs included the following:

A flyer from one of the SJBEP workshops (in Spanish).

Translation: Workshop for the Evaluation of Risks in the Communities of the San Juan Bay Estuary

- Climate Change 101 presentation describing the science, the global impacts, the island-wide Puerto Rico impacts, and selected risks to the estuary area as determined by the initial risk identification (Step 3).

- Open discussion questions to collect pre-determined information from the participants to inform Step 4 of the CRE Guidebook.

- "Live polling" where each participant was given a handset and the opportunity to vote instantly on a number of specific questions to assist with the Step 4 of the CRE Guidebook. The results of the live polling were immediately presented to the group in order to encourage more in-depth group discussions.

The presentation's agenda was:
1)Welcome and explanation of Climate Ready Estuaries initiative
2) Presentation- Current and Future Climate Risks in Puerto Rico and San Juan Bay Estuary Program
3)Section of questions to identify risks and vulnerabilities
4)Collective Discussion (set concerns and perceptions about how climate change affects the community)

One-on-one consultations with conducted throughout the process. The expert list to consult was comprised of members from the Puerto Rico Climate Change Council (PRCCC) and from relevant agencies and university programs.

Some of the questions that were conducted at community meetings were:
1) What event affects your business activities or your daily life? The majority of people answered that stronger precipitation events affects business and everyday lifestyle.
2) Most people agree that the beach erosion is affecting daily activities and business
3) The main concern people have as an individual to the impacts of climate change is private property and yet the main concern for the community are the natural barriers.

Community meetings helped us know how the communities perceive the impacts of climate change on their community and also give us information about their concerns as a community and as individuals.

Questions used for open discussion questions and “live polling” were:

What assets are the most important to your community? (a) value of the coast; (b) community identity; (c) culture; (d) economy; (e) health

Which of these impacts caused by climate change would cause major economic loss, social or environmental? (a) effects on flora and fauna; (b) infrastructure loss; (c) effects on the coast; (d) effects on public health

What environmental problems already exist in your community?

(a) Wastewater discharges
(b) Erosion
(c) Floods
(d) Contamination
(e) Waste management
(f) Health
(g) Infrastructure maintenance
(h) Drinking water services
(i) Electric services
(j) Other(s)?

Are the following events already occurring or going to occur in the future?
Fish kills; Water contamination; Days with intense heat affecting your activities or businesses; Desirable fish species moving out of the area for more suitable habitat; Coastal erosion affecting your business or activities; More common occurrences of jellyfish.

Choose the principal concern that you have for your home, community or business with climate change impacts. Impacts to:
natural characteristics that protect the coast; wildlife in the estuary; private property structures; public buildings and facilities; transportation (bridges, roads, ports); energy generation infrastructure; water storage and services; historical and cultural resources.

Peer-Review

Each step of the process included consultation before moving on to the next step, but the most intensive peer-review came after the risk analysis. With 167 risks identified a peer review for each individual analysis was not possible, however, the analyses with the lowest confidence or the organizational objectives with the highest engaged reviewers received an in-depth peer review through one-on-review sessions. After completion of this report it is planned to have a formal review with the full SJBEP Scientific and Technical Advisory Committee before determining distribution and outreach of the vulnerability assessment results.

Additions to EPA's Draft CRE Guidebook

The SJBEP process we went through were the same as laid out in the CRE Guidebook (steps 1-5) with a few modifications we adopted and communicated to the EPA CRE office throughout the process via email, phone calls and in-person workshop in Washington, DC with National Estuary Program staff and managers from the other NEP programs.

The principal modification made was to put a strong emphasis on engaging the environmental justice communities that live and work around the bay, lagoons, and canals of the estuary system. Engaged occurred via the workshops and individual conversations, including field visits to Caño Martin Peña Communities, fishermen in the lagoons, and forest managers in the Piñones State Forest. These discussions with the estuary communities were particularly productive as we were able to listen and learn from the experiences and opinions of those who live in different parts of the estuary system. All communities reported that contaminated water and inundations were already greatly affecting the activities of families and businesses. Some were able to tell stories of past hurricane events and how their communities were isolated due to flooding or did not have electricity for as much as six months. This information was then used to inform the risk analysis and risk evaluation steps.

In the original draft CRE it was not advised to look for and utilize if possible previously conducted state or regional vulnerability assessments. Because of the SJBEP's active participation in the Puerto Rico Climate Change Council (PRCCC) we drew heavily from the State of the Climate Report 2010-2013[2] for the risk identification and analysis. In the supplemental risk analysis excel spreadsheet each risk analysis identifies whether the risk came from the EPA guidebook, the PRCCC or one of the workshops. And for certain risks, the scientific source/ confidence level cites the PRCCC report.

Additionally, we added three columns to risk analysis spreadsheet that were not included in the CRE Workbook: "where was risk identified?", "mentioned in community workshops (Y/N)", "notes", and we changed source/confidence to "scientific source/confidence".

[2] http://drna.gobierno.pr/oficinas/arn/recursosvivientes/costasreservasrefugios/pmzc/prccc/prccc

Results from Steps 1 to 5 of the CRE Guidebook

CRE Guidebook Step 1: Communication and Consultation

Objective of this step
The objective of this step is to list your key stakeholders and their particular interest or concerns regarding climate change risks and the vulnerability assessment process. This step will also help you identify communication schedules.

At the beginning of the risk management process, it is important to communicate to stakeholders the purpose of the vulnerability assessment and the level of involvement you are requesting of them. It is also important that decision makers within your organization understand what you are trying to accomplish and the expected outcomes of this process. Some groups may be involved throughout the entire process, while others may have a particular interest in a single step or area of focus.

Stakeholder	Issue/Area of Focus	When should/did they become involved?
Angel Dieppa, Jobos Bay NERR		September workshop
Benito Pinto, La Regata	Recreational/Navigation/Fishing	September workshop
Craig Lilyestrom, DNER	Marine Resources/Fisheries	September workshop
David Cuevas, EPA	Water resources	September workshop
Ernesto Diaz, DNER-PRCZMP	Coastal hazards, development, nonpoint and point sources of pollution, public access	September workshop
Ernesto Olivares, SJBEP	Enforcement	September workshop
Evelyn Huertas, EPA		September workshop
Gustavo Garcia, SJBEP and DNER Assistant to Secretary	Public Policy	September workshop
Jorge Bauza, SJBEP	ALL	September workshop
Jose Rivera, NOAA		September workshop
Jose Seguinot Barbosa	Public health, water quality	September workshop
Julio Morell, CariCOOS	Monitoring, modeling and data management	September workshop
Katia Aviles, Proyecto ENLACE	Environmental justice communities, health, water quality, recreation, fisheries, marine resources	September workshop

Luis Jorge Herrera, IDS		September workshop
Luis Soler, USGS		September workshop
Pablo Mendez, UPR/SJBEP		September workshop
Pedro Diaz, USGS	Monitoring	September workshop
Pedro Gelabert, SJBEP	ALL	September workshop
Pedro Guevara, JCA	Water quality	September workshop
Ray David Rodriguez, Fideicomiso		September workshop
Raimundo Espinosa, TNC		September workshop
Vance Vicente		September workshop
Jorge Ortiz Zayas, UPR-ITES		September workshop
Ernesto Otero, RUM_CIMA		September workshop
Angel Melendez, JCA	Water quality	September workshop
Jose Juan Terrasa, Turismo	Recreation, coastal hazards, marine resources	September workshop

CRE Guidebook Step 2: Establishing the Context

Objective of this step
The objective of this step is to identify your organizational objectives to establish the context of your vulnerability assessment.

Source: San Juan Bay Estuary Program's Management Plan July 2000
Notes – relevant to CRE Guidebook
Goals of the Program:

- Establish a comprehensive water quality policy. This policy will ensure the integrity of marine resources and terrestrial ecosystems while supporting human activities in the SJBE system.
- Develop an effective administrative and regulatory framework for the SJBE system that will serve as a model for other estuary systems, especially for tropical systems.
- Optimize the social, economic, and recreational benefits, which have been associated with the SJBEP system
- Prevent further degradation and improve the system's water quality to help ensure healthy terrestrial and aquatic communities and social well-being
- Minimize the health risks associated with direct human contact with the surface waters and the consumption of fish and shellfish

Objectives of the SBJEP:

- Identify the major stressors impacting the system and establish their relative importance
- Develop action plans to remediate the problems identified in the system
- Conserve and enhance the integrity of the known, highly valuable natural resources in the SJBE system, and restore, to the extent possible, those areas which have been adversely impacted
- Address the major concerns of the citizens and user groups have regarding the quality of the system
- Promote the public's awareness regarding estuarine resources and involvement in the development of an effective management plan for the system
- Develop a hydrological model of the system to determine effective alternatives to improve circulation and predict hdydrological impacts of future development (pg. 15)

Themes of Clean Water Act §320, and the Estuary and Clean Waters Act of 2000 (from CRE Guidebook)

- Control point and nonpoint sources of pollution and clean up of pollution
- Maintain and improve estuarine habitat
- Protect and propagate fish, shellfish, and wildlife, including control of nonnative species
- Protect public water supplies and

Organization's Goals & Objectives	Does it correspond with one of the clean water themes? (Y/N)
GOAL 1: Water and Sediment Quality/Aquatic Debris (new actions: solid waste management and green infrastructure) • Eliminate direct and indirect sewage discharges to the various canals and lagoons of the SJBE to reduce nutrient and pathogen loadings and increasing human uses of estuarine waters • Improve water circulation in the SJBE to enhance its flushing capacity resulting in an improvement of its waters and sediments • Reduce nutrient and toxics loadings from nonpoint sources which result in an impairment of the estuary's habitats and uses • Avoid the detrimental effects of oil and other contaminants on water and sediment quality, habitats, estuarine species, and socioeconomic activities • Reduce levels of oil and grease, nutrients, sediments, toxics and other pollutants in municipal storm sewer point source discharges which result in the degradation of estuary habitats and uses • Significantly reduce the amount of aquatic debris that reaches all estuarine waters • Develop, promote, and implement voluntary compliance and pollution prevention initiatives • Strengthen the enforcement of littering laws and regulations • NEW: Establish pilot projects of contaminant prevention en freshwater tributaries of the San Juan Bay Estuary • NEW: Promote use of green infrastructure in San Juan Bay Estuary Watershed	**YES**
GOAL 2: Habitat, Fish and Wildlife • Preserve and restore ecologically important habitat • Protect species relative abundance and diversity • Enhance economically viable fisheries resources and ensure their sustainability	**YES**
GOAL 3: Public Engagement and Involvement (new actions: education and community participation and social communication) • Increase the public's awareness of the estuary's functions and values	**NO**

CRE Guidebook Step 3: Risk Identification

Objective of this step

To generate a comprehensive *list* of climate change risks that might affect (positively or negatively) the ability of your organization to achieve its objectives. This Step will develop that list.

POLLUTION CONTROL:
Water and Sediment Quality/Aquatic Debris (new actions: solid waste management and green infrastructure)

	WARMER	WARMER "WINTERS"	WARMER "SUMMERS"	WARMER WATER	MORE FREQUENT DROUGHT	MORE INTENSE PRECIPITATION	SEA LEVEL RISE	INCREASED CARBON DIOXIDE/OCEAN ACIDIFICATION
NON-POINT SOURCES OF POLLUTION (NPS)				*Higher solubility may lead to higher concentration of pollutants already existing in lagoon or newly entering lagoon(EPA; PRCCC)*	*NPS pollution may rise from the buildup of pollutants on land, followed by high intensity flushes (EPA)*	*Streams may see greater erosion (EPA)*	*Tides may reach higher and flood new areas (EPA; PRCCC)*	*Decomposing organic matter release CO_2 which may exacerbate the ocean acidification problem in coastal waters with increasing NPS pollution from increasing precipitation (EPA). Coastal ocean acidification can occur when excess CO_2 is absorbed by, flushed into, or generated in coastal waters setting off a chain of chemical reactions that lowers the waters pH (Woods Hole Oceanographic Institute)*
				Increased toxicity of	*Decreased*	*Urban areas may*		

				pollutants that already exist in lagoon (EPA; PRCCC)	*concentration of some contaminants due to less transport by runoff (SJBEP WKSHP)*	*be subject to more floods (EPA; PRCCC).*		
				Water may hold less dissolved oxygen (DO) (EPA; PRCCC)		*Flood control facilities (e.g., detention basins, manure management) may be inadequate (EPA)*		
				Higher surface temperatures may lead to stratification (EPA; PRCCC)		*Excess rainfall may cause septic systems to fail (EPA).*		
				Greater algal growth may occur (EPA; PRCCC)		*Increase in runoff (SJBEP WKSHP)*		
				Parasites, bacteria may have greater abundance, survival or transmission (EPA; PRCCC)		*Dilution factor (SJBEP WKSHP) And Evento de Lavado (no entiendo esto evento de lavado) – extreme runoff events/flash flood increasing contaminants, but with increasing rain increasing dilution of*		

						contaminants.		
POINT SOURCES OF POLLUTION & POLLUTION CLEANUP		*Increased demand for air conditioning, increased used of power plants. More thermal discharge into the estuary, increasing carbon dioxide into the atmosphere, and more water used as input for the power plants (SJBEP WKSHP).*		*Temperature criteria for discharges may be exceeded (thermal pollution) (EPA)*	*Critical low-flow criteria for discharging may not be met (EPA)*	*Combined sewage overflows may increase (EPA; PRCCC)*	*Treatment plants may not be able to discharge via gravity at higher water levels (EPA; PRCCC)*	
	Aumento de descargas de gases (SJBEP WKSHP) – igual a arriba			*Warmer temperatures may increase toxicity of pollutants (EPA; PRCCC) by evapotransporation (SJBEP WKSHP) (maybe more toxicity from process of evapotransportation*	*Pollutant concentrations may increase if sources stay the same and flow diminishes (EPA)*	*Treatment plants may go offline during intense floods (EPA; PRCCC)*	*Treatment infrastructure may be susceptible to coastal flooding (EPA; PRCCC)*	
				– water…)				
				Increasing sound pollution penetration (NEED CITATION)			*Seawater may enter combined sewer systems (EPA)*	
							Contaminated sites may flood or have shoreline erosion (EPA; PRCCC)	
							Sewers may have more inflow (floods) or infiltration (higher watertable) (EPA; PRCCC).	
							Obstructions to discharge points (SJBEP WKSHP)- look up discharge permits for SJBEP – do we have maps or information about discharge permits/points in the estuary?	

Habitat, Fish and Wildlife

	WARMER	WARMER "WINTERS"	WARMER "SUMMERS"	WARMER WATER	MORE INTENSE PRECIPITATION	MORE FREQUENT DROUGHT	SEA LEVEL RISE	INCREASED CARBON DIOXIDE/OCEAN ACIDIFICATION
PHYSICAL & HYDROLOGIC FEATURES	*Higher temperatures may lead to greater evaporation and lower groundwater tables (EPA)*		*Increase in nutrients in estuary as a consequence of vegetation die-off (SJBEP WKSHP)*	*Warmer water may lead to greater likelihood of estuarine stratification (EPA; PRCCC)*	*The number of storms reaching an intensity that cause problems may increase (EPA).*	*Base flow in streams may decrease (EPA)*	*Shoreline erosion may lead to loss of beaches, wetlands and salt marshes (EPA; PRCCC)*	
	Switching between surface and groundwater sources for public water supplies may affect the integrity of estuaries – Jorge: what do you think about this for the estuary? More consumption of water because of heat and Less freshwater to the lagoon			*Eutrophication and hypoxia (SJBEP WKSHP)*	*Stronger storms may cause more intense flooding and runoff (EPA; PRCCC), especially from oversaturated storm drains (SJBEP WKSHP)*	*Groundwater tables may drop (EPA)*	*Freshwater habitat may become brackish (EPA; PRCCC)*	
	Loss of plant cover (SJBEP				*Coastal overwash or*	*Stream water may*	*Tidal influence*	

	WKSHP)				*breaching of barriers may occur (EPA; PRCCC)… "changes in geomorphology" (SJBEP WKSHP)*	*become warmer (EPA)*	*may move farther upstream (EPA; PRCCC)*	
	Change in forest structure (SJBEP WKSHP) - Piñones				*Turbidity of surface waters may increase (EPA) and sedimentation in certain estuarine areas (SJBEP WKSHP)*	*Runoff decreases thus decreasing sediment (SJBEP WKSHP)*	*Saline water may move farther upstream (EPA; PRCCC)*	
	Increased water consumption will lead to increased water withdrawals, reducing the ecological flow (SJBEP WKSHP)				*Increased intensity of precipitation may yield less infiltration (EPA).*	*Increase in salinity of water bodies (SJBEP WKSHP)*	*Bulkheads, sea walls, and revetments may become more widespread (EPA; PRCCC)*	
					Downed trees and other vegetation may close off small channels of SJBE (Occurrence – 1998 in Caña Martin Peña. Personal Communication)		*Changes in circulation of lagoons (SJBEP WKSHP)*	
					Long-term changes could affect biotic functions such as community structure and productivity and physical processes such as nutrient cycling (PRCCC – Michener et al. 1997).		*Reduction in the thickness of the freshwater lens (SJBEP WKSHP)*	
					Reduced salinity (SJBEP WKSHP)			
CONSTRUCTION OF REEFS TO PROMOTE FISH AND SHELLFISH				*Desired fish may not stay around (EPA)*			*Light may not penetrate through deeper water (EPA)*	*Long-term shellfish sustainability may be an open question (EPA)*
				Warmer water may promote invasive species or disease (EPA).	*Stream erosion may lead to high turbidity and greater sedimentation (EPA)*		*Higher salinity may kill targeted species (EPA)*	*Fish may be adversely affected during development stages (EPA)*
					Lower pH from NPS pollution may affect target species (EPA)			

ANIMALS AND PLANTS:
Habitat, Fish and Wildlife

	WARMER	WARMER "WINTERS"	WARMER "SUMMERS"	WARMER WATER	MORE INTENSE PRECIPITATION	MORE FREQUENT DROUGHT	SEA LEVEL RISE	INCREASED CARBON DIOXIDE/OCEAN ACIDIFICATION
PROTECTION & PROPAGATION OF FISH, SHELLFISH & WILDLIFE **CONTROL OF NONNATIVE AND INVASIVE SPECIES** **MAINTAIN BIOLOGICAL INTEGRITY & REINTRODUCE NATIVE SPECIES**	*Species that won't tolerate warmer conditions may die/migrate; biota at the extent of their range may disappear from local ecosystems (EPA; PRCCC; SJBEP WKSHP), especially amphibians and insects (bees) (SJBEP WKSHP)*	*Species that used to migrate to San Juan might stay away all winter due to warmer conditions in other areas. (modified EPA)*	*Increase in mortality of corals (SJBP WKSHP)*	*Newly invasive species may appear (EPA)like the Cayepuet – promulgate with fires (release the seeds).* *(Brazilian pepper)* *More concern for temperate climates, because tropical species migrate. In tropics not really an issue.*	*Greater soil erosion may increase turbidity and decrease water clarity (EPA)*	*Species may not tolerate a new drought regime (EPA)*	*Sea level may push saltier water farther up stream (especially of interest with regard to shellfish habitat) (EPA)*	*Shellfish may not survive the stress (EPA)*
	Species may be weakened by heat and become out-competed (EPA)	*Species that once migrated through may stop and stay in Puerto Rico or stop in points further north than they used to and no longer come to Puerto Rico (modified EPA)*	*Increased biological activity of alien species like the iguana. Increased predation (SJBEP WKSHP)*	*Habitat may become unsuitably warm for a species, its food, or reproduction (modified EPA). Example: certain coquis stop calling above a certain temperature*	*Greater soil erosion may increase sediment deposition in estuaries with consequences for benthic species (EPA; PRCCC)*	*Freshwater flow in streams may be diminished (EPA)*	*Light may not penetrate through the full depth of deeper water (EPA; PRCCC)*	*Shellfish predators may not survive the disappearance of shellfish (EPA)*
	Essential food sources may die off or disappear affecting the food web (EPA)	*Pests may survive winters that used to kill them (EPA)....Increase/long-term/chronic... reproduction of amphibians and insects (SJBEP WKSHP)*	*Changes in migration patterns of invasive species (SJBEP WKSHP)*	*Heat may stress immobile biota (EPA)*	*Changes in microbial populations may have a domino effect (SJBEP WKSHP) – N/A*	*Changing freshwater inputs may affect salinity distribution in estuaries (especially of interest with regard to shellfish habitat) (EPA)*	*Greater coastal wetland losses may occur (EPA; PRCCC)*	*Fish may be adversely affected during development stages (EPA; PRCCC)*
	Species may need to consume more water as temperatur	*A longer growing season may lead to an extra reproductive cycle (this might be more relevant to changing wet/dry in*		*Dissolved oxygen capacity of water may drop (EPA; PRCCC)*		*Reduced habitat of freshwater fish with lower*	*Inland migration of mangroves (SJBEP WKSHP)*	*The effect of ocean acidification on calcifying plankton may lead to cascading*

	e rises (EPA)	*tropics). Reproduction of insects, plants, amphibians butterflies in wet season. More dry – decrease reproduction; more wet – increase reproduction (aquatic insects – nymph stages)…*		*leading to more fish kills (SJBEP WKSHP)*		*water levels (SJBEP WKSHP)*		*effects in the food chain (EPA; PRCCC)*
		Food supplies and migrating birds may get mis-timed (check with FWS; check Jorge Salivas section in PRCCC)		*Coral bleaching episodes may increase (EPA; PRCCC; SJBEP WKSHP)*	*Difficult to introduce native species (SJBEP WKSHP) – which species in particular? Dr. Lugo?*	*Difficult to introduce native species (SJBEP WKSHP)*	*Increased vertical growth of mangroves (SJBEP WKSHP)*	*Temperature-driven increased biological activity may act to raise pH in estuaries (counter to the ocean trend) (EPA) NEED CITATION – ANECDOTAL FROM ANOTHER NEP, but basically increased numbers of plants and increased metabolic rates drive more photosynthesis which takes up more CO2.*
		Disease of corals and organisms (SJBEP WKSHP)		*Parasites and diseases are enhanced by warmer water (EPA; PRCCC)*	*Decreased populations of dinoflagellates (SJBEP WKSHP)*	*Increased drought in Sahara desert produces increased*	*Changes in species succession (SJBEP WKSHP)*	*Decreased calcification (reefs and other organisms) (SJBEP WKSHP)*

						transport of Saharan dust that brings disease causing fungi and diseases to corals (SJBEP WKSHP)		
		Increased length of stay of migratory birds (SJBEP WKHP)		*Decreased populations of dinoflagellates (SJBEP WKSHP)*	*Increased distribution of tilapia (SJBEP WKHP)*	*Increased mortality of amphibians and insects (bees) (SJBEP WKSHP)*	*Increase in resuspension (SJBEP WKSHP)*	
		Affects patterns of organism reproduction (SJBEP WKSHP)		*Increased biological activity of alien species like the iguana. Increased predation (SJBEP WKSHP)*			*Increased salinity favors a reduction in freshwater habitats (SJBEP WKSHP)*	
				Species like Caiman disperse covering a larger area (SJBEP WKSHP)	*Species like Caiman disperse covering a larger area (SJBEP WKSHP) (why with increasing precipitation?) – because they have more wet*		*Increased difficulty for reef placement (SJBEP WKSHP)*	

					habitat			

HUMAN USES

	WARMER	WARMER "WINTERS"	WARMER "SUMMERS"	WARMER WATER	MORE INTENSE PRECIPITATION	MORE FREQUENT DROUGHT	SEA LEVEL RISE	INCREASED CARBON DIOXIDE/OCEAN ACIDIFICATION
RECREATIONAL ACTIVITIES IN & ON THE WATER	*Too hot for enjoyment of outdoor recreational activities (PRCCC)*	*Less tourism due to northern areas being warmer, less recreational use of water bodies (PRCCC; SJBEP WKSHP)*	*Too hot for enjoyment of outdoor recreational activities (PRCCC)*	*Harmful algal blooms may be more likely (EPA; PRCCC)*	*More frequent or more intense bad weather may decrease recreational opportunities (EPA) and reduce the activity of bathers (SJBEP WKSHP)*	*Freshwater flows in streams may not support recreational uses like boating, kayaking, fishing, or SUP (EPA) – no reports of this.*	*Beaches or public access sites may be threatened by coastal erosion or inundation (EPA; PRCCC)*	*Eco-tourism resources or attractions may be degraded (e.g., birding, diving, fishing) (EPA; PRCCC)*
		Increased use of vessels (SJBEP WKSHP)	*Increase in nautical activities (SJBEP WKSHP)*	*Jellyfish may be more common (EPA) NEED CITATION - jury is out on this (it's a risk). However jellyfish thrive in warmer water. No reports in SJBE*	*Greater NPS pollution may impair recreation (EPA; PRCCC) as a result of bacterial contamination (SJBEP WKSHP)*	*Increased estuary salinity may drive away targeted recreational fish (EPA)*	*Critical clearance under bridges may decrease (EPA; PRCCC)*	*Recreational shellfish harvesting may be lost (EPA)*
		Increased	*Increased use*	*Open seasons*	*Increased*	*Increased use*	*Reduction of*	

		recreational fishing charter ships (SJBEP WKSHP) (Difference in winter fishing over summer in PR?) -	*of water bodies (SJBEP WKSHP)*	*and fish may become mis-aligned (EPA). Meaning that the dates of the fishing season and the presence of the regulated fish might get out of alignment as the fish arrive/depart sooner/later.*	*aquatic security risks (SJBEP WKSHP)*	*of water bodies for recreational purposes (SJBEP WKSHP)*	*the beaches (SJBEP WKSHP)*	
		Perception of better recreational fishing for tarpon (SJBEP WKSHP) – why in warmer winter? Craig Lilyestrom	*Aumento de desperdicios sólidos (SJBEP WKSHP) – more people using the beach and recreation areas; more people = more trash*	*Desired fish may not be around (EPA; PRCCC)*			*Impacts to hotel infrastructure as a product of erosion (SJBEP WKSHP)*	
		Decrease of dry days in winter (SJBEP WKSHP)		*Invasive plants may clog creeks, canals, and waterways (modified EPA)*				
PROTECTION OF PUBLIC WATER SUPPLIES	*Warmer temperatures may drive greater water*		*Utilización del embalse las curias como suministro de*		*Water infrastructure may be vulnerable to*	*Freshwater flow may not keep salt water below*	*Sea level may push salt fronts upstream*	

	demand (EPA)		*agua, reduciendo asi el aporte de agua dulce al estuario (SJBEP WKSHP). La Curia (lake – source of rio piedras). If we have to use the wáter from here, we don't do that now, less wáter to estuary*		*flooding (EPA; PRCCC)*	*intakes (EPA)*	*past water diversions (EPA) – Evelyn Huertas*	
	Evaporation losses from reservoirs and groundwater may increase (EPA)		*Increased pressure to reservoirs that supply the metropolitan population (SJBEP WKSHP)*	*Changes in treatment processes may be required (EPA)*	*Flood waters may raise downstream turbidity (EPA)*	*Groundwater tables may drop (EPA)*	*Water infrastructure may be vulnerable to inundation or erosion (EPA; PRCCC)*	
				Increased growth of algae and microbes may affect drinking water quality (EPA)		*Groundwater may be salinized from insufficient freshwater input (EPA)*	*Saltwater intrusion into groundwater may be more likely (EPA; PRCCC) and therefore less potable water available (SJBEP WKSHP)*	

						Groundwater may be salinized from higher demand on aquifers (EPA)	*Sewers may have more inflow (from floods) or infiltration (from higher water table) (EPA)*	
						Maintaining passing flows at diversions may be difficult (EPA) – check with SJBEP if there are regulated water diversions within the estuary watershed that if water levels get too low then water withdrawal would be restricted- checking with Evelyn Huertas		
						Less freshwater available and possibility of water rationing (SJBEP WKSHP)		
						Less freshwater available and possibility of use of desalinization plants (SJBEP WKSHP)		
COASTAL & ESTUARINE RESOURCE USE (SUBSISTENCE) (KJ ADDED)							*Reduced access to coastal resources for fishing, traditional products, etc (KJ)*	

CRE Guidebook Step 4: Risk Analysis

Objective of this step
The objective of this step is to qualitatively determine the spatial scale of the impact, likelihood, consequence, and the time until a problem begins for the climate change risks identified in **Step 3** - Risk Identification, so they can be sorted into high, medium, and low categories of impact.

For risk analysis results see supplemental excel spreadsheet.

CRE Guidebook Step 5: Risk Evaluation

Objective of this step
The objective of this step is to develop a consequence/probability matrix and review it with stakeholder input to help determine which risks the SJBEP organization will address in future adaptation planning.

Results of this step are below through a series of risk matrices. The matrices are a categorization of all foreseeable climate related risks based on their likeliness of occurrence and consequence to the SJBEP' organization's goals and objectives. The risks identified in red are the highest risk because their consequence and likelihood were identified as high in Step 4, those in yellow are medium risk, and those in green are low risk. Those risks that were identified to have a positive outcome for the SJBEP are clearly marked "POSITIVE". All others are considered negative outcomes.

POLLUTION CONTROL: Water and Sediment Quality/Aquatic Debris (new actions: solid waste management and green infrastructure)

NON-POINT SOURCES OF POLLUTION

Likelihood (probability) of Occurrence	**High**		1. Greater algal growth may occur from warmer waters (place or region within estuary; 15-30 years) 2. Water may hold less dissolved oxygen from warmer water (site; already occurring)	1. Increase in runoff from more intense precipitation (estuary-wide; already occurring) 2. Excess rainfall may cause septic systems to fail (estuary-wide; already occurring) 3. Urban areas may be subject to more floods from more intense precipitation estuary-wide; already occurring) 4. Higher solubility may lead to higher concentration of pollutants already existing in lagoon or newly entering lagoon (estuary-wide; within the next 15-30 years) 5. Flood control facilities (e.g., detention basins, manure management) may be inadequate (estuary-wide; decades) 6. Parasites, bacteria may have greater abundance, survival or transmission from warmer water (places or regions within estuary; already occurring) 7. Obstructions to discharge points from sea level rise causing contaminants to overflow inland (places or regions within estuary; already occurring) 8. Streams may see greater erosion due to sea level rise carrying more sediment into estuary (places or regions within the watershed; already occurring) 9. Tides may reach higher and flood new areas from sea level rise that are contaminant sources (places or regions within estuary; 15-30 years)

	Medium		1. NPS pollution may rise from the buildup of pollutants on land, followed by high intensity flushes (site; 15-30 years)	2. Increased toxicity of pollutants that already exist in lagoon from warmer waters (place or region in estuary; 15-30 years)
	Low	**1.** Decreased concentration of some contaminants due to less transport by runoff from more frequent drought (estuary-wide; decades) **2.** Higher surface temperatures may lead to stratification (site; decades) **3.** Decreased sound absorption increasing sound penetration and noise pollution (place or region; decades)	1. POSITIVE: Extreme runoff events/flash flood increasing contaminants, but with increasing rain increasing dilution of contaminants (estuary-wide; decades) 2. "Coastal acidification": Decomposing organic matter release CO_2 which may exacerbate the ocean acidification problem in coastal waters with increasing NPS pollution from increasing precipitation (place or region in estuary; decades)	
		Low	**Medium**	**High**
		Consequence of Impact		

POINT SOURCES OF POLLUTION

Likelihood (probability) of Occurrence				
	High		1. Increased demand for air conditioning, increased use of power plants. More thermal discharge into the estuary due to warmer "winters" (and increasing CO_2 into the atmosphere) (site; already occurring) 2. Temperature criteria for discharges may be exceeded due to warmer water (thermal pollution) (site; 15-30 years)	1. Combined sewage overflows may increase due to more intense precipitation (estuary-wide; already occurring) 2. Sewers may have more inflow (floods) or infiltration (higher watertable) due to sea level rise (estuary-wide; 15-30 years) 3. Seawater may enter combined sewer systems (estuary-wide; 15-30 years) 4. Pollutant concentrations may increase if sources stay the same and flow diminishes due to more frequent drought (estuary-wide; decades) 5. Obstructions to discharge points from sea level rise causing contaminants to overflow inland (place or region; already occurring) 6. Treatment plants may go offline during intense floods (site; already occurring) 7. Treatment plants may not be able to discharge via gravity at higher water levels (site; decades)
	Medium		1. Treatment infrastructure may be susceptible to coastal flooding due to sea level rise (site; 15-30years)	1. Critical low-flow criteria for discharging may not be meet due to more frequent drought (estuary-wide; decades) 2. Contaminated sites may flood or have shoreline erosion due to sea level rise (site; decades)

	Low		1. Increased demand for air conditioning due to warmer "winters", increased use of power plants (increasing CO_2 into the atmosphere). And more water used as input for the power plants (site; already occurring)	1. Warmer temperatures may increase toxicity of pollutants by evapotransportation (place or region; decades)
		Low	**Medium**	**High**
		Consequence of Impact		

ESTUARY HABITAT: Habitat, Fish & Wildlife

PHYSICAL & HYDROLOGICAL FEATURES

Likelihood (probability) of Occurrence				
	High	1. Increased intensity of precipitation may yield less infiltration (estuary-wide; already occurring) 2. Switching between surface and groundwater sources for public water supplies may affect the integrity of estuaries (aka More consumption of water because of heat and less freshwater to the lagoon and more land subsidence, saltwater intrusion, etc). (estuary-wide; decades) 3. Loss of plant cover (site; decades) 4. Change in Forest Structure (Piñones) (site; decades) 5. Increased water consumption will lead to increased water withdrawals, reducing the ecological flow (estuary-wide; decades)	1. Bulkheads, sea walls and revetments may become more widespread (sites; already occurring) 2. Tidal influence/saline water may more farther upstream (sites; decades) 3. Coastal overwash or breaching of barriers may occur…changes in geomorphology (estuary-wide; already occurring) 4. Increase in salinity of water bodies, affecting the toxicity of metals and pH (place or region; decades) 5. Runoff decreases thus decreasing sediment (estuary-wide; within the next 15-30 years)	1. Reduction in the thickness of the freshwater lens (estuary-wide; already occurring) 2. Stronger storms may cause more intense flooding nd runoff, especially from oversaturated storm drains (estuary-wide; already occurring) 3. Eutrophication and hypoxia (place or region; already occurring) 4. Increase in nutrients in estuary as a consequence of vegetation die-off (eutrophication) (place or region; already occurring) 5. Shoreline erosion may lead to loss of beaches, wetlands and salt marshes (extensive; already occurring) 6. The number of storms reaching an intensity that cause problems may increase (estuary-wide; within the next 15-30 years) 7. Downed trees and other vegetation may close off small channels of SJBE (place or region; within the next 15-30 years) 8. Stream water may become warmer because depth decreases (place or region; decades) 9. Groundwater table may drop (extensive; decades) 10. Base flow in streams may decrease (place or region; decades) 11. Higher temperatures may lead to greater evaporation and lower groundwater tables (aka groundwater depletion leading to land subsidence and saltwater intrusion)(places or regions; decades)
	Medium	1. Warmer water may lead to greater likelihood of estuarine stratification (site; decades)		2. Reduced salinity (lagoons and canals; places or regions)

	Low	**4.** Freshwater habitat may become brackish (site; decades)		
		Low	**Medium**	**High**
		Consequence of Impact		

CONSTRUCTION OF REEFS TO PROMOTE FISH AND SHELLFISH

Likelihood (probability) of Occurrence	Consequence of Impact: Low	Consequence of Impact: Medium	Consequence of Impact: High
High			
Medium	3. Long-term shellfish sustainability may be an open question (site; within the next 15-30 years) 4. Lower salinity may depress growth rates of Mangrove Oyster (site; within the next 15-30 years)	1. Stream erosion may lead to high turbidity and greater sedimentation (place or region; within the next 15-30 years) 2. Higher temperatures may "bleach" the coral that settles on artificial reefs (site; within the next 15-30 years) 3. Fish may be adversely affected (place or region; decades) 4. Warmer water may promote invasive species or decease (place or region; already occurring)	1. Desired fish may not stay around (place or region; within the next 15 to 30 years)
Low	**5.** Light may not penetrate through deeper water (site; decades) **6.** Higher salinity may kill targeted shellfish species (site; within the next 15-30 years) **7.** Lower salinity may kill targeted shellfish species (site; within the next 15-30 years) **8.** Higher temperatures may kill targeted shellfish species (site; within the next 15-30 years)	1. Lower pH from NPS pollution may affect target species (place or region; decades)	1. Higher salinity may kill targeted reef species (estuary-wide; decades)

Animals & Plants: Habitat, Fish & Wildlife

PROTECTION & PROPAGATION OF FISH, SHELLFISH & WILDLIFE

CONTROL OF NONNATIVE AND INVASIVE SPECIES

MAINTAIN BIOLOGICAL INTEGRITY & REINTRODUCE NATIVE SPECIES

Likelihood (probability) of Occurrence	**High**		1. Coral bleaching episodes may increase (place or region; already occurring) 2. Increase in mortality of corals (place or region; already occurring) 3. Disease more prevalent in corals and organisms (place or region; within the next 15-30 years)	1. Species like Caiman disperse covering a larger area because they have more wet freshwater habitat (place or region; already occurring) 2. Increased salinity favors a reduction in freshwater habitats (place or region; already occurring) 3. Altered populations (quantity) of dinoflagellates and diatoms (place or region; already occurring or soon to occur) 4. Greater soil erosion may increase turbidity and decrease water clarity affecting primary production, coral and seagrass growth (estuary-wide; already occurring) 5. Greater soil erosion may increase sediment deposition in estuaries with consequences for benthic species (estuary-wide; already occurring or soon to occur) 6. Harmful algal blooms may be more likely (estuary-wide; within the next 15-30 years) 7. Decreased calcification (reefs and other organisms) (estuary-wide; within the next 15-30 years) 8. Dissolved oxygen capacity of water may drop leading to more fish kills (estuary-wide; within the next 15-30 years) 9. Greater coastal wetland losses may occur (estuary-wide; within the next 15-30 years) 10. Freshwater flow in streams may be diminished (estuary-wide; decades)

	Medium	1. Increased vertical growth of mangroves (place or region; decades) 2. Food supplies and migrating birds may get mis-timed (site; decades) 3. Reduced habitat of freshwater fish with lower water levels (site; soon) 4. Species that once migrated through may stop and stay in Puerto Rico or stop in points further north than they used to and no longer come to Puerto Rico (place or region; within the next 15-30 years) 5. Species may need to consume more water as temperature rises (place or region; decades) 6. Sea level may push saltier water farther upstream (especially of interest with regard to shellfish habitat) (site; within the next 15-30 years) 7. Species that used to migrate to San Juan might stay away all winter due to warmer conditions in other areas (site; within the next 15-30 years)	1. Increased biological activity of alien species like the iguana leading to increased predation (place or region; within the next 15-30 years) 2. Fish may adversely affected during development stages (place or region; decades) 3. Species may be weakened by heat and become outcompeted (place or region; decades) 4. Newly invasive species may appear like the Cayeput – promulgate with fires (extensive; decades)	1. Mangrove productivity increases (POSITIVE) (site; soon to occur) 2. Mangrove productivity decreases (NEGATIVE) (site; decades) 3. Increased difficulty for reef placement (place or region; decades) 4. Increased distribution of tilapia (place or region; within the next 15-30 years) 5. Increased drought in Sahara desert produces increased transport of Saharan dust that brings disease causing fungi and diseases to corals (place or region; within the next 15-30 years) 6. Parasites and diseases are enhanced by warmer water (place or region; within the next 15-30 years) 7. Difficult to introduce native species (site; decades) 8. The effect of ocean acidification on calcifying plankton may lead to cascading effects in the food chain (estuary-wide; within the next 15-30 years) 9. Species may not tolerate a new drought regime (estuary-wide; decades) 10. Shellfish may not survive the stress (estuary-wide; decades) 11. Shellfish predators may not survive the disappearance of shellfish (place or region; decades) 12. Species that won't tolerate warmer conditions may die/migrate; biota at the extent of their range may disappear from local ecosystems (place or region; within the next 15-30 years) 13. A longer growing season may lead to an extra reproductive cycle (this might be more relevant to changing wet/dry in tropics). Reproduction of insects, plants, amphibians, butterflies in wet season. More

	Low	1. Temperature driven increased biological activity may act to raise pH in estuaries (counter to the ocean trend) (place or region; within the next 15-30 years) 2. Heat may stress immobile biota (site; decades) Pests may survive winters that used to kill them (site; decades) 3. Light may not penetrate through the full depth of deeper water due to sea level rise (place or region; decades)	1. Habitat may become unsuitably warm for a species, its food, or reproduction (ex. Certain coquis stop calling above a certain temperature) (extensive; within the next 15-30 years)	1. Species like Caiman disperse covering a larger area due to warmer water (place or region; decades) 2. Inland migration of mangroves (extensive; decades) 3. Essential food sources may die off or disappear affecting the food web (place or region; decades)
		Low	**Medium**	**High**
		Consequence of Impact		

Human Uses

RECREATIONAL ACTIVITIES IN AND ON THE WATER

Likelihood (probability) of Occurrence	High	1. Open seasons and fish may become misaligned (place ore region; decades)	1. Increased occurrence of Ciguatera fish poisoning (extensive; already occurring or soon to occur) 2. Desired fish may not be around (extensive; decades) 3. More frequent or more intense bad weather may decrease recreational opportunities and reduce the activity of bathers (place or region; within the next 15-30 years) 4. Increased recreational fishing charter ships (place or region; decades) 5. Critical clearance under bridges may decrease (site; decades)	1. Increase in solid waste – more people using the beach and recreational activities (extensive; already occurring) 2. Greater NPS pollution may impair recreation as a result of bacterial contamination (extensive; already occurring) 3. Beaches or public access sites may be threatened by coastal erosion or inundation (place or region; already occurring) 4. Impacts to hotel infrastructure as a product of erosion (site; already occurring) 5. Increased aquatic security risks (place or region; within the next 15-30 years) 6. Harmful algal blooms may be more likely (extensive; within the next 15-30 years) 7. Increase in nautical activities (place or region; within the next 15-30 years)

	Medium		1. Decrease of dry days in winter impacting tourism industry (place or region; within the next 15-30 years) 2. Freshwater flows in streams may not support recreational uses like boating, kayaking, fishing or stand-up paddleboarding (SUP) (place or region; decades) 3. Less tourism due to northern areas being warmer, less recreational use of water bodies (place or region; already occurring or soon to occur) 4. Too hot for enjoyment of outdoor recreational activities (place or region; already occurring or soon to occur)	1. Eco-tourism resources or attractions may be degraded (e.g., birding, diving, fishing) (extensive; decades)

	Low	1. Recreational shellfish harvesting may be lost (place or region; decades)	1. Increased estuary salinity may drive away targeted recreational fish (place or region; decades)	1. Invasive plants may clog creeks, canals and waterways reducing public access (extensive; decades) 2. Jellyfish may be more common (place or region; within the next 15-30 years) 3. Increased use of vessels (place or region; decades)
		Low	**Medium**	**High**
		Consequence of Impact		

Likelihood (probability) of Occurrence	**High**	1. Saltwater intrusion into groundwater may be more likely (place or region; within the next 15-30 years) 2. Groundwater may be salinized from higher demand on aquifers (place or region; within the next 15-30 years) 3. Groundwater may be salinized from insufficient freshwater (place or region; within the next 15-30 years) 4. Less freshwater available and possibility of water rationing (extensive; decades) 5. Warmer temperatures may drive greater water demand and increase pressure to reservoirs (site; decades)		1. Water infrastructure may be vulnerable to flooding (extensive; already occurring) 2. Changes in treatment processes may be required (site; already occurring or soon to occur) 3. Water infrastructure may be vulnerable to inundation or erosion (extensive; decades) 4. Sewers may have more inflow (from floods) or infiltration (from higher water table) (extensive; decades) 5. Evaporation losses from reservoirs and groundwater may increase (site; decades)

	Medium			1. Groundwater tables may drop (extensive; decades) 2. Freshwater flow may not keep salt water below intakes (extensive; decades)

	Low		1. Because of increased water demand, using the old Las Curias reservoir as water supply, thus reducing freshwater input to the estuary (place or region; decades)	1. Less freshwater available and possibility of use of desalinization plants (extensive; decades) 2. Increased growth of algae and microbes may affect drinking water quality (site; decades) 3. Sea level may push salt fronts up stream past water diversions (site; decades)
		Low	**Medium**	**High**
		Consequence of Impact		

COASTAL & ESTUARINE TRADITIONAL RESOURCE USE

Likelihood (probability) of Occurrence	**High**		1. Reduced access to coastal resources for fishing, traditional products, etc. (site; decades)	
	Medium			
	Low			
		Low	**Medium**	**High**
		Consequence of Impact		